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Factors Modulating Memory-based  
Deception Detection in Concealed Information Tests

By

Danielle Grace Norman

A thesis submitted in partial fulfilment of the requirements for the degree of  
Doctor of Philosophy in Psychology.

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Department of Psychology

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## List of Abbreviations

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|  |   |                   |
|--|---|-------------------|
| Concealed Information Test               | - | CIT               |
| Reaction Times                           | - | RTs               |
| Skin Conductance Responses               | - | SCR               |
| Magnitude of Heart Rate Change           | - | $\Delta$ HR       |
| Electrodermal Activity                   | - | EDA               |
| Electrocardiogram                        | - | ECG               |
| The normalized response to crime stimuli | - | CIT Effect        |
| Virtual Reality                          | - | VR                |
| Event related potential component        | - | P300              |
| Interstimulus Interval                   | - | ISI               |
| Standard deviation                       | - | SD                |
| Bayes Factor for the null hypothesis     | - | BF <sub>01</sub>  |
| Analysis of Variance                     | - | ANOVA             |
| Receiver Operator Curve                  | - | ROC               |
| Area under the Curve                     | - | AUC               |
| Standard Error                           | - | SE                |
| 95% Confidence Interval                  | - | CI <sup>95%</sup> |
| Milliseconds                             | - | ms                |
| Partial Eta Squared Effect Size          | - | $\eta_p^2$        |
| Mean Square Error                        | - | MSE               |
| Mean Difference                          | - | MD                |

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Last but not least, thank you Alison for all your support and patience throughout! At least you can now share in my fame and fortune that comes with being with a PhD graduate! Not sure when that bit starts...

## Declaration

This thesis is submitted to the University of Warwick in support of my application for the degree of Doctor of Philosophy. It has been composed by me and has not been submitted in any previous application for any degree. The work presented (including data generated, processed and analysis) was carried out by the author except in the cases outlined below.

In this thesis, data collected for:

- Experiment 3, Chapter 2 was carried out by an MSc student.
- Experiments 2 and 3, Chapter 3 were carried out by two individual undergraduate finalists.
- Experiments 1 and 2, Chapter 4 were carried out by two pairs of undergraduate finalists.
- Experiment 2, Chapter 6 was carried out by a pair of undergraduate finalists. Note, another pair of undergraduate finalists piloted this experiment, but this data is only included in Chapter 8.

Data collection for the above seven experiments was carried out under close supervision of the author with all other aspects of the study (e.g. concept, planning, experimental design and set-up and analysis) carried out solely by the author. Data collection for the remaining thirteen experiments was conducted by the author.

**Presentation of Thesis.** Not including references, tables and appendix, this thesis is within the 70000 University word limit (630 pages, 82 figures and 6 tables).

## **Inclusion of Published Work**

Parts of this thesis have been submitted, or are intended to be submitted, for publication by the author. Note, Prof Derrick Watson has supervised all aspects of the thesis and provided helpful comments on each draft manuscript - additional authors and their contributions are specified.

- Chapter 5 has been published in *Journal of Applied Research in Memory and Cognition* with the following authors and title:
  - *Norman, D.G., Wade, K., Williams, M.A., & Watson, D.G., (2020)*  
*Caught virtually lying: Crime scenes in virtual reality help to expose suspects' concealed recognition.*
  - Prof Mark Williams consulted on the digital technologies used and Dr Kimberley Wade has provided helpful comments on the draft manuscript.
- Chapter 2 has been accepted with corrections to *Memory and Cognition* with the following authors and title:
  - *Norman, D.G., Gunnell, D., Mrowiec, A., & Watson, D.G., Seen this Scene? Scene recognition in the Reaction-Time Concealed Information Test*
  - Daniel Gunnell assisted in the technical set up of experiments 1-2 and reviewed the manuscript. Aleksandra Mrowiec collected the data for Experiment 3 and reviewed the manuscript.

- Part 1 of Chapter 3 has been submitted to the *Journal of Experimental Psychology; Memory, Learning and Cognition* with the following authors and title:
  - *Norman, D.G., & Watson, D.G., (submitted) Partners in crime: Group testing increases the detection of concealed information for crime collaborators*
- Chapter 4 has been submitted to the *Law and Human Behavior* with the following authors and title:
  - *Norman, D.G., & Watson, D.G., (submitted) What do you know? Informed investigators may not increase false positives in concealed information tests*
- Chapter 8 has been accepted as a conference poster to the *International Conference On Behavioural And Social Sciences In Security, 2020* with the following authors and title:
  - *Norman, D.G., & Watson, D.G., (2020) Mega-analysis: Self-reported motivation, stress, performance and countermeasure use in picture-based concealed information tests*
- Submission of Chapter 6-7 is under consideration.

## Other published work by the Author

### Journal Papers

- Gunnell, D.O.A., Kumar, M., **Norman**, D.G., and Watson, D.G., (2019) The Hazards of Perception: Evaluating a change blindness demonstration within a real-world driver education course. *Cognitive Research: Principles and Implications*
- **Norman**, D.G., Baier, W., Watson, D.G., Burnett, B., & Williams, M.A., (2018) Micro-CT and Quantitative Analysis of Saw Marks in Human Bone. *Forensic Science International*
- **Norman**, D.G., Watson, D.G., Burnett, B., and Williams, M.A., (2018) The cutting edge - Micro-CT for quantitative toolmark analysis of sharp force trauma to bone. *Forensic Science International*
- Baier\*, V., **Norman\***, D.G., Warnett, J.M., Harrison, N.P., Payne, M., Hunt, N.C.A., Burnett, B.A., and Williams, M.A., (2017) Novel application of three-dimensional technology in a case of dismemberment. *Forensic Science International*, (\*joint contribution)
- **Norman**, D.G., Metcalfe, A., Timothy, B., Hutchinson, C.E., Thompson, P.J.M., Spalding, T., and Williams, M.A., (2016) Cortical Bony Thickening of the Lateral Intercondylar Wall: The Functional Attachment of the Anterior Cruciate Ligament. *The American Journal of Sports Medicine*
- **Norman**, D.G., Getgood, A., Thornby, J., Bird, J., Turley, G.A., Spalding, T., and Williams, M.A., (2014) Quantitative topographic anatomy of the femoral ACL footprint: a micro-CT analysis. *Medical & Biological Engineering & Computing*

- Thornby, J., Landheer, D., Williams, T., Barnes-Warden, J., Fenne, P., **Norman**, D.G., Attridge, A., and Williams, M.A., (2014) Inconsistency in 9 mm bullets: Correlation of jacket thickness to post-impact geometry measured with non-destructive X-ray computed tomography. *Forensic Science International*

### Conference talks

- **Norman**, D., Wade, K., & Watson, D.G., (2018) Social Factors and the Physiological Concealed Information Test, *European Association of Psychology and Law, Turku*
- **Norman**, D., Thornby, J., Bird, J., Getgood, A., Thompson, P., Williams, M. A. and Spalding, T., (2012) Quantitative topographic anatomy of the anterior cruciate ligament femoral footprint — do the ridges exist? *Knee Surgery, Sports Traumatology, Arthroscopy, Geneva*
- **Norman**, D.G., (2012) Quantitative topographic anatomy of the anterior cruciate ligament femoral footprint. *British Association of the Knee Conference, Derby*
- **Norman**, D.G., (2013) Weapon-Wound Matching of Sharp Force Trauma to Bone – A Micro-CT Analysis. *British Conference of Undergraduate Research, Plymouth*

### Conference Posters

- Alsop, K., **Norman**, D.G., Baier, W., Burnett, B.A. and Williams, M.A., (2019) Metric Toolmark Analysis Using Micro-CT. *Annual Congress of the International Society of Forensic Radiology and Imaging, Berlin*



- **Norman, D.G., Gunnell, D., Wade, K., Williams, M.A., & Watson, D.G., (2016)**  
Assessing the Concealed Information Test: Countermeasures, Stimuli, Group and Measures. *European Association of Psychology and Law, Toulouse*
- **Norman, D.G., Gunnell, D., Wade, K., & Watson, D.G., (2015)** Have you seen this scene? A concealed information task for scene recognition. *Deception: International Conference on Deceptive Behaviour, Cambridge*
- **Norman, D.G., & Watson, D.G., (2013)** Determining, Measuring and Testing Quantitative Signatures of Deceptive Behaviour. *British Conference of Undergraduate Research, Plymouth*
- **Norman, D.G., Getgood A., Bird, J., Spalding, T., & Williams, M.A., (2013)**  
Quantitative Topographic Anatomy of the Femoral ACL Footprint - A Micro-CT Analysis. *British Conference of Undergraduate Research, Plymouth*
- **Norman, D.G., Burnett, B., Gibbons, G.J., Barnes-Warden, J., Williams, M.A., (2012)** Re-engineering forensic anthropology: new techniques in sharp force trauma analysis. *Undergraduate Research Conference, Coventry*
- **Norman, D.G., & Williams, M. A., (2012)** Extraction of High-Resolution Bone Surface Topology from Micro-CT for Identification of Osseous Landmarks. *British Conference of Undergraduate Research, Coventry*
- **Norman, D.G., Burnett, B., Barnes-Warden, J., & Williams, M. A., (2012)**  
Weapon-Wound Matching of Sharp Force Trauma to Bone using Micro-CT – A Methodology and Pilot Study. *Forensics Horizons Conference, Coventry*
- **Norman, D.G., Finnegan, M.E., & Collingwood J.F., (2011)** Analysing the Impact of Iron Dysmetabolism on Regional Metal Ion Distribution in the Brain. *Undergraduate Research Scholarship Scheme, University of Warwick*

## **Author Profile**

### ***Including research projects and work undertaken alongside her PhD***

Danielle a doctoral researcher working within the Behavioural Science Group, Department of Psychology at the University of Warwick. Following her Master's degree in Systems and Computer Engineering, Danielle secured a PhD scholarship in Behavioural Science researching the Concealed Information Test – a memory-based deception detection test (viva passed December 2019).

Alongside her PhD, Danielle has worked as lead researcher and engineer on a range of projects within metrology, forensic science, and anatomy and has developed a track record of delivering on industry-funded projects totalling £120k. She has presented academic work nationally and internationally and published seven (seven first author) articles in international journals. As part of her forensic work, she has provided expert evidence to the West Midlands and, in formal recognition of her contribution, received the Chief Constable's award. During her PhD, Danielle has also taught on a range of undergraduate modules including; "Psychology and the Law" and "Research Methods in Psychology" and guest lectured for Coventry University's MSc Forensic Psychology course. She has also co-supervised a dozen 3rd-year project students and research interns.

Danielle also served as a reservist in the British Army alongside her studies and currently volunteers as a member of the University Residential Team where she is responsible for maintaining discipline and pastoral support and welfare within student halls. Outside of work, Danielle is a keen footballer and squash player, playing in regional leagues.



## Thesis Summary

Scientists have developed various deception detection methods to assist investigating officers working across a range of contexts from terrorism to insurance fraud. One of the most theoretically grounded and diagnostic deception tests is the Concealed Information Test (CIT) which is advocated by researchers and systematically applied in Japanese criminal cases. The CIT relies on theories of memory and attention to detect a suspect's recognition of crime information placed amongst various control stimuli. Two CIT approaches are explored in this thesis. The first is the already established physiological CIT (measuring heart rate and skin conductance) whose validity has been demonstrated following decades of research and field application. The other is a recently proposed computer-based oddball task called the reaction-time CIT (RT-CIT) which also shows promise in the lab.

Following a brief introduction to the scope of this thesis [1], a variety of unanswered questions relating to CITs are investigated. For example: Can we test crime scene recognition with the RT-CIT? [2]; When a crime is committed by a pair, should they be given a CIT together and what is the impact when their knowledge is shared? [3]; What dangers (or benefits) are there in using a human investigator to conduct the CIT? [4]; Can virtual reality be used to improve recognition and consequently CIT detection? [5]; What is the effect of administering a delayed CIT? [6]; Can the concept of verticality be exploited in the RT-CIT to increase detection? [7] and finally; what is the relationship between self-reported; motivation, stress, performance and countermeasure use in the CIT? [8]. Theoretical and practical implications for the CIT as a memory-based deception test, discussed and future research opportunities identified [9]. Overall, this work demonstrates that the CIT's diagnosticity can be affected by various factors explored in this thesis.



## CHAPTER 1

### **What's CIT all about?**

#### **A brief introduction to concealed information test and the theses outline**

##### **Summary**

This chapter provides a brief introduction to the Concealed Information Test (CIT) before outlining the contents of the remaining chapters. Each of the experimental chapters in this thesis contains a discrete CIT study (designed for submission to peer reviewed journals) although share common themes and methodologies discussed in this introduction. As each experimental chapter contains its own detailed introduction, only a brief overview of the CIT paradigms used through this thesis are presented - suggestions for recent reviews of the topics discussed are provided. Following this, an overview of the remaining chapters is provided, with each of their planned contributions to knowledge described.

## **Deception Detection**

Whether you are a professional lie catcher or not, you are typically only just better than chance at detecting deception ([Bond Jr & DePaulo, 2006](#)). Hence, it is unsurprising that scientists have explored various techniques to assist with this important task (for two thorough reviews of the deception literature see [Vrij, \(2008\)](#), with more updated findings presented in [Granhag, Vrij and Verschuere, 2015](#)). The use of physiological measures, such as changes in heart rate, to detect deception is primarily associated with the well-known polygraph or 'lie detector test'. In the polygraph, specifically the Control/Comparison Question Test (CQT), deception is inferred from changes in suspects' physiological responses between control and critical questions. For example, responses to the critical question e.g. "Did you steal the money?" are compared to e.g. "Have you ever stolen anything in your life?" The idea is that guilty suspect shows a stronger physiological response to the critical questions whereas innocent suspects show the opposite effect ([Ambach, & Gamer, 2018](#)). Unfortunately, this approach has received much criticism from the scientific community due to the lack of theoretical basis and standardization however this debate, typically between practitioners and researcher is ongoing ([Fienberg et al., 2003](#) on behalf of the National Research Council).

## **The Concealed Information Test**

An alternative approach to detect deception is to determine what information the suspect has about the crime. To appear innocent, guilty suspects usually conceal incriminating knowledge about the crime particularly when the details have yet to be released by the media or the investigating authorities. So how can we detect a suspect's concealed recognition of crime information that an innocent person would not know? The Concealed Information Test (CIT) is a memory detection tool

designed to do exactly this and has been researched and applied systematically and used as forensic evidence in the Japanese criminal system for decades ([Osugi, 2011](#)).

For two accessible and thorough reviews of CIT literature see Verschuere, Ben-Shakhar and Meijer ([2011](#)) and more recently Rosenfeld ([2018](#)).

Unlike other lie detection approaches, the CIT aims to detect deception through the measurement of a suspect's recognition to specific crime related details. In this sense the CIT does not detect deception per se but rather aims to detection specific recognition. Because of this specificity, the CIT is considered more theoretically grounded than other deception tools and is supported by deception scientists. So how might a CIT work? Consider an example where the perpetrator breaks into a university building using bolt cutters, covers a CCTV camera with shaving foam, before then stealing some items. They then give these stolen items to another person in a car park. The police identify a number of potential suspects and through CCTV determine what was used to break the lock and cover the CCTV camera. Additionally, the police get a description from a witness reporting a suspicious exchange of valuable items in a car park. Finally, the police have a suspicion of who received the stolen items. In this scenario the CIT could consist of five crime related details, i.e. bolt cutters, shaving foam, the building, car park and the accomplice (e.g. [Figure 1.1](#)) not known by an innocent suspect. In the CIT, these five crime details would be presented randomly and sequentially amongst five equally plausible options, much like a multiple-choice questionnaire (e.g. [Figure 1.2](#)). One question could be "Did you use this tool to break into the building?" with images of five different plausible tools then presented, one being the bolt cutter. Another question might be "Was this the person you handed the stolen items to?" followed by different faces with one being the suspected accomplice. A person



without knowledge of the crime, i.e. an innocent suspect, would be unable to discriminate the crime from control items. In a physiological CIT,<sup>1</sup> the suspect's recognition of crime details via physiological responses (typically skin conductance, heart rate) to 'crime items' (aka probes, such as the bolt cutters or the building broken into) is compared with their responses to non-crime related stimuli, 'control items' (aka irrelevants, such as other tools that can break a lock or other buildings in the vicinity of the burgled building). Compared with controls, crime items produce a larger physiological response, such as an increased skin conductance response (SCR), as predicted by orienting theory which is taken as an indication of recognition of those items (e.g., [Figure 1.3](#)). In addition to orienting measured recognition, arousal inhibition experienced by the suspect lying and suppressing the truth causes guilty suspects' heart rate to slow down or decelerate ( $\Delta HR$ ) ([Verschuere, Ben-Shakhar & Meijer, 2011](#)). The difference in magnitude of the physiological recognition response to crime items versus control items is known as the CIT effect. Through measuring orienting, and sometimes arousal inhibition, the CIT is highly diagnostic ( $AUC = 0.85$ ,  $n = 3863$ , [Meijer et al. 2016](#)) at detecting concealed recognition, with minimal false positives (i.e. concluding that an innocent suspect recognizes the crime item).

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<sup>1</sup> In this thesis a "physiological CIT" represents a CITs that uses measure of the Autonomic Nervous System such as heart rate and skin conductance.

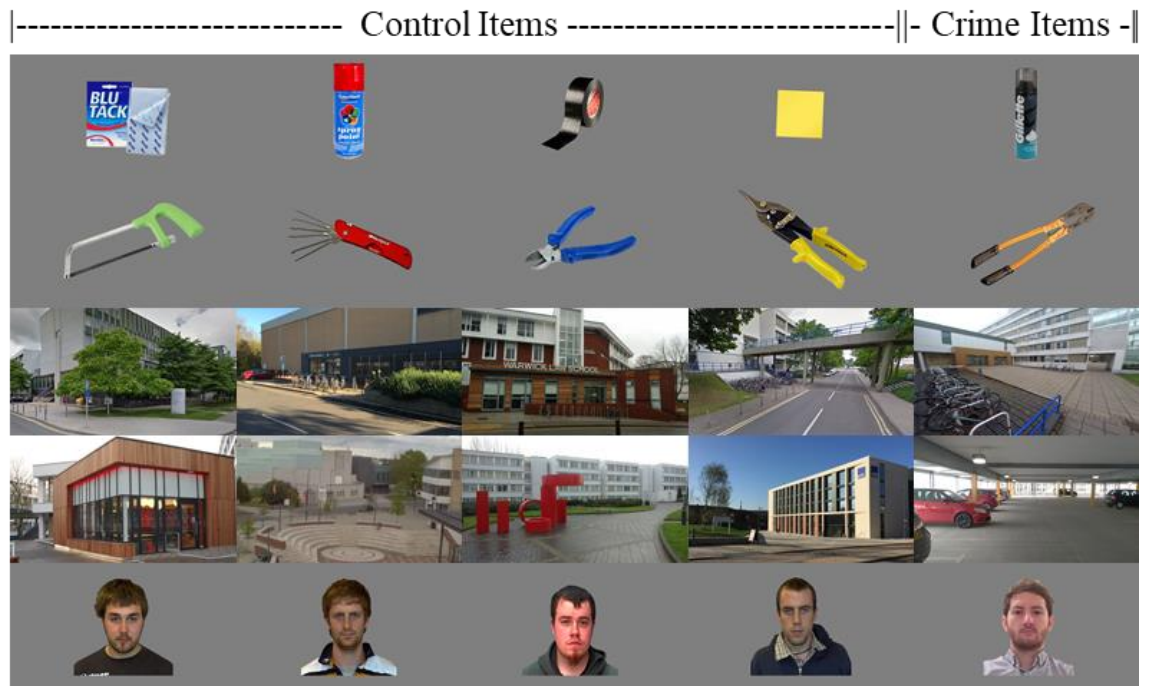


Figure 1.1. Example of stimuli that could be presented to a suspect in a CIT where the perpetrator has broken into a building with bolt cutters, covered a CCTV camera with shaving foam and then stolen some items, before selling these to an accomplice within a car park.

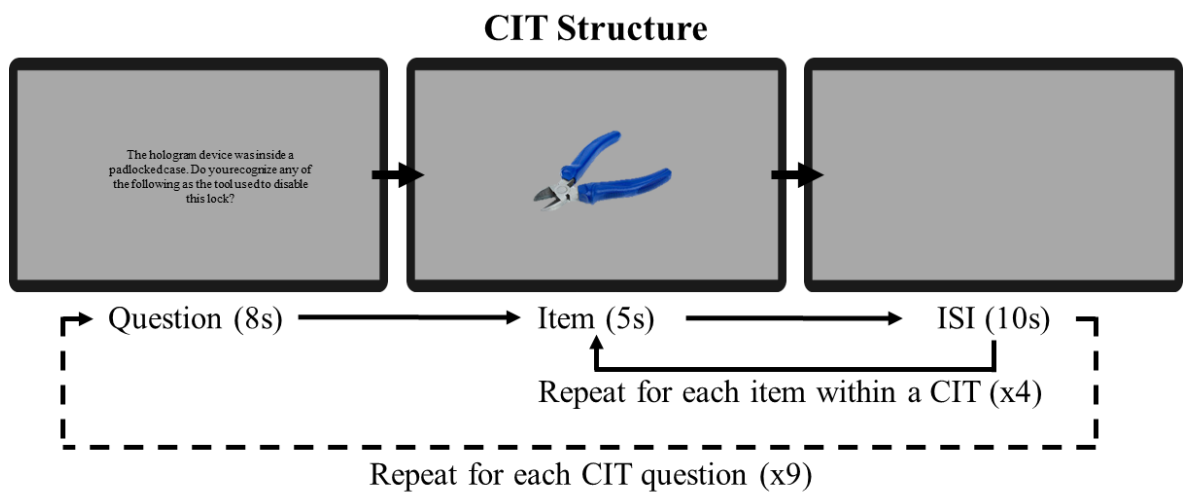


Figure 1.2. Example of how image stimuli are presented to suspects in a physiological CIT including approximate timings

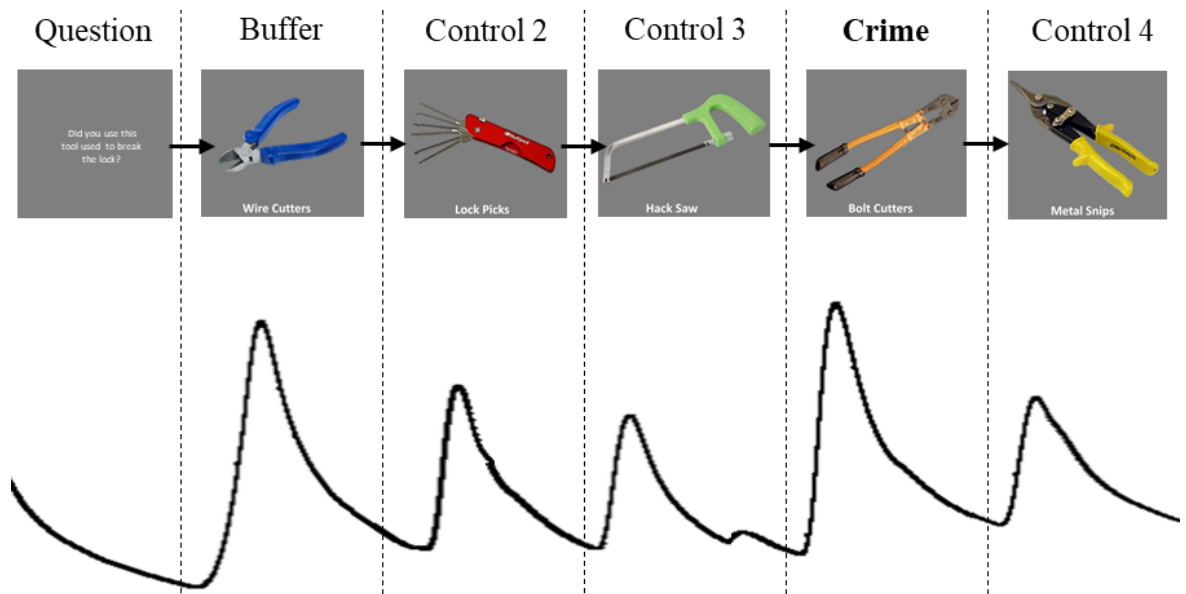


Figure 1.3. Example typical skin conductance response to image stimuli for guilty suspects where the crime item is the bolt cutters

### Reaction Time CIT

The reaction time Concealed Information Test (RT-CIT) is a relatively recent CIT paradigm that uses reaction times (RTs) rather than physiological responses to detect concealed information. This test is based on the finding that concealing knowledge of a crime requires inhibition of the truth, leading to an overall slowing of responses made to crime-related items (for a review see [Verschuere, Suchotzki, & Debey, 2015](#)). The RT-CIT has some advantages over the physiological based CIT as it is cheaper, faster, simpler to administer, easier to analyze and does not require specialist training or equipment. In brief, the RT-CIT is an oddball task in which participants respond, using a keyboard, to a sequence of briefly presented stimuli. Each RT-CIT trial consists of the presentation of one of three types of stimulus: a *crime*, a *control*, and a *target* item ([Figure 1.4](#)). Participants respond 'no' to indicate that they do not recognize either the crime or the control items. The third type of stimuli are target items which consist of a set of images that the participant is shown before the test and are instructed to respond 'yes' to. If target items were not present,

participants could complete the task with 100% accuracy simply by pressing the ‘no’ key and without having to process the stimuli adequately enough for the test to be effective.

Typically, guilty suspects are slower to respond ‘No’ (untruthfully), that they do not recognize a crime item, than they are to respond ‘No’ (truthfully), that they do not recognize a control item. It is largely agreed that this slowing is due to response inhibition experienced by participants whilst they resolve the conflict between actually recognizing an object yet having to report deceptively that they do not (Debey, Ridderinkhof, De Houwer, De Schryver, & Verschuere, 2015). Furthermore, this conflict sometimes results in an increased number of errors, for example, pressing ‘Yes’ to the crime items or ‘No’ to the target items (Suchotzki, Verschuere, Van Bockstaele, Ben-Shakhar, & Crombez, 2017). The target items serve no diagnostic role and are simply presented to ensure that participants are processing the stimuli and engaging with the task. Studies conducted using the RT-CIT have shown that it can be just as diagnostic as the physiological-based CIT ( $AUC = .82$   $n = 981$ , Meijer et al., 2016).

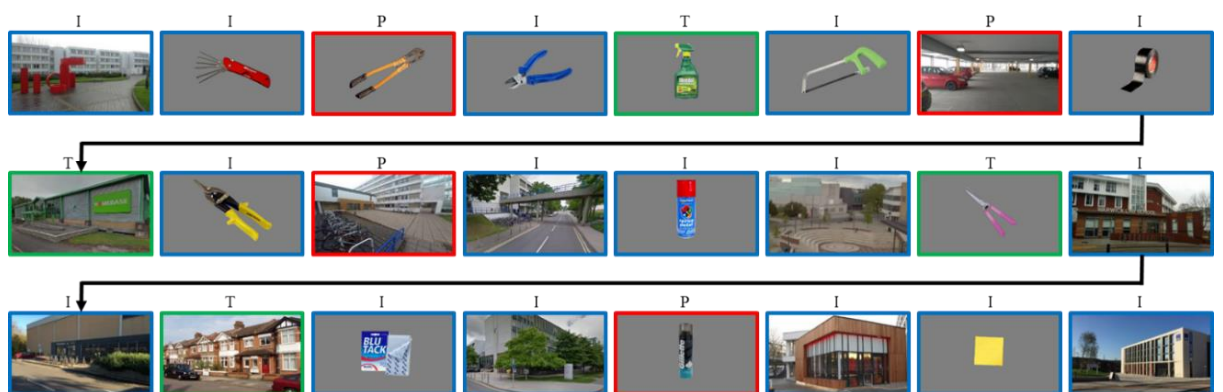


Figure 1.4. Example of one block of 24 images in an RT-CIT containing four crime items (red and ‘P’) each with four controls (blue and ‘I’) and one target (green and ‘T’).

## Thesis Outline

Although, simplistically, the CIT effect is generally considered to be driven by recognition and inhibition, various factors have been found to modulate it, including but not limited to: suspect motivation; countermeasure use; the number of crime items used; whether recognition is concealed or not; crime memory; whether crime information has leaked to innocent suspects; and the effect of simulating innocent suspects' data for establishing baseline detection rates ([Meijer, Selle, Elber & Ben-Shakhar, 2014](#); [Ben-Shakhar & Elaad, 2003](#); [Suchotzki, Verschuere, Van Bockstaele, Ben-Shakhar & Crombez, 2017](#)). Other modulating factors less understood include social influence from either a CIT administrator/investigator or crime collaborator.

However, there remain interesting yet unanswered questions in both the physiology and RT-CIT which are experimentally explored in this thesis ([Figure 1.5](#)). In short these questions are: Are scene stimuli, e.g. the crime scene, suitable for use in the RT-CIT? (Chapter 2); When a crime is committed by a pair, should they be given a CIT together and what is the impact when their knowledge is shared? (Chapter 3); What dangers are there in using a human investigator to conduct the CIT? (Chapter 4); Can virtual reality be used to improve CIT detection by facilitating memory? (Chapter 5); What is the effect of administering a delayed CIT and is it similar to presenting faded stimuli? (Chapter 6); Can vertical metaphorical associations (lying is immoral) be incorporated to increase RT-CIT detection? (Chapter 7) and finally; What is the relationship between self-reported motivation, stress, performance and countermeasure use in the CIT? (Chapter 8). Each chapter is described individually below.

**Chapter 2.** Increasing the range and type of possible stimuli that can be used to test a suspect's recognition of a crime is important, as more CIT questions have been shown to increase overall detection of guilt (Meijer et al., 2014). In Chapter 2, the possibility of using scenes in the RT-CIT is explored as scenes are known to be processed differently to object stimuli. For example, compared to objects: scenes require encoding into memory over several glances (Melcher, 2006); recognition is possible without complete identification (Cleary & Reyes, 2009); scene information is processed rapidly requiring fewer attentional resources (Munneke et al, 2013); and the PPA brain region responds only to scenes (Oliva & Torralba, 2006). The work in Chapter 2 determined: i) if scene stimuli can produce similar sized CIT effects seen in the literature; ii) whether scene stimuli differ from object stimuli in the RT-CIT; and iii) the susceptibility of scene-based RT-CITs to a physical countermeasure strategy.

**Chapter 3.** High profile criminal activity is often planned and carried out by groups of people with each member having individual roles and knowledge about the crime (Zheng, Messner, Lu & Deng, 1997). Group testing in the CIT is used to extract hidden information from crime groups (e.g., Elaad, 2016). However, the effects of social influence in group CIT testing, compared to individual testing, and what information each suspect has been exposed to, has yet to be systematically investigated. This topic is explored in Chapter 3 by having pairs of participants view a mock crime video from the 1<sup>st</sup> person perspective of two thieves carrying out a heist together. During this heist, the thieves encounter crime information together or individually before undergoing a physiological CIT either together or separately (Experiments 1-3). In the second part of Chapter 3, participant pairs are tested together in a group RT-CIT whilst concealing recognition of autobiographic scenes

(Experiment 4), before determining whether the group-based RT-CIT differed from individual testing (Experiment 5). Finally, the procedure in Experiment 2 is repeated but using an RT-CIT (Experiment 6).

**Chapter 4.** Deception is a social act; however, CITs are often administered with minimal social interaction. This is because theories from social psychology caution against using investigators who are knowledgeable about the crime when administering forensic assessments of witness or suspect memory ([Rosenthal, 2002](#); [Perlini & Silvaggio, 2007](#)). However, other theories suggest using an investigator may be beneficial ([Hancock, Woodworth, & Gorrha, 2010](#)). Accordingly, in Chapter 4, the effects of potential social influence by the investigator are explored. The work directly tests the impact of using a human investigator, blind to the suspects' guilt, to administer a physiological CIT face-to-face to both guilty and innocent suspects. Guilty suspects only, watched a mock crime video, thereby encoding eight crime details which the human investigator knew. In Experiment 1 (within-subjects) and Experiment 2 (between subjects), either an investigator sat opposite the suspect asking each question, followed by presenting photographs of the stimuli in a structured CIT fashion, or a computer was used to present the CIT.

**Chapter 5.** Facilitating memory retrieval either through the use of CIT stimuli that closely match the encoded memory, or by matching encoding and retrieval modality (e.g. verbal or visual) has been shown to increase CIT detection ([Ben-Shakhar & Gati, 1987](#); [Rosenfeld, Ward, Frigo, Drapekin, & Labkovsky, 2015](#)). In Chapter 5, participants are given a novel CIT in virtual reality where the mock crime details (two rooms and two objects) were presented as photo-realistic 3D, 1:1 scaled models. This was compared against an equivalent CIT with 2D images presented instead. This was to determine: i) whether memory retrieval is superior in

VR compared to 2D images; and ii) whether a VR-CIT offers increased diagnosticity as a forensic memory detection test.

**Chapter 6.** Related to Chapter 5, the effects of memory in the CIT are explored; specifically, the effects of a long - and realistic - time delay between crime and CIT which has been shown to affect CIT detection ([Ben-Shakhar & Nahari, 2018](#)). Participants were given a CIT, either within a week or approximately two months following a mock crime task, in which they were not explicitly instructed to remember any details. Following this experiment, an unplanned follow-up experiment was developed to explore the effects of gradually fading CIT image stimuli onto the screen in an attempt to simulate reduced recognition due to forgetting.

**Chapter 7.** Deception is important in the RT-CIT, as it is thought to contribute to the response inhibition experienced by guilty suspects when responding to the crime items. Verticality (relative positioning of stimuli in the vertical dimension) has been linked to various metaphoric associations such as high/up equating to positive/moral whereas low/down equals negative/immoral ([Cian, 2017](#); [Meier & Robinson, 2004](#); [Crawford et al., 2006](#); [Meier, Sellbom & Wygant, 2007](#)). For guilty participants, crime items requiring a deceptive response are incompatible with concepts of positivity/moral and may therefore slow processing and RTs in the direction of the RT-CIT effect. Over three experiments this is explored by presenting image stimuli either at the top or bottom of the screen to determine whether verticality interacts positively with the RT-CIT.

**Chapter 8.** Motivation of the suspect to avoid detection appears to increase CIT detection rates ([Meijer et al., 2014](#)) but could also relate to whether countermeasures (attempts to fool the test) are used by the suspect, which



consequently tend to decrease the CIT effect (Meijer et al., 2014). Furthermore, stress during the CIT and a suspect's self-perceived lying ability have also been shown to benefit CIT detection (Elaad, 2018). In many of the experiments conducted as part of this thesis, participants were given a questionnaire to complete following the CIT. These measured participants' self-reported motivation to avoid detection, stress felt during the CIT, perceived performance at avoiding detection, and whether or not they used a countermeasure and if so what. Using this data, a mini meta-analysis was conducted to explore these additional factors not considered in the previous chapters.

**Chapter 9.** Finally, concluding remarks, theoretical and practical insights are discussed, and further work recommended.

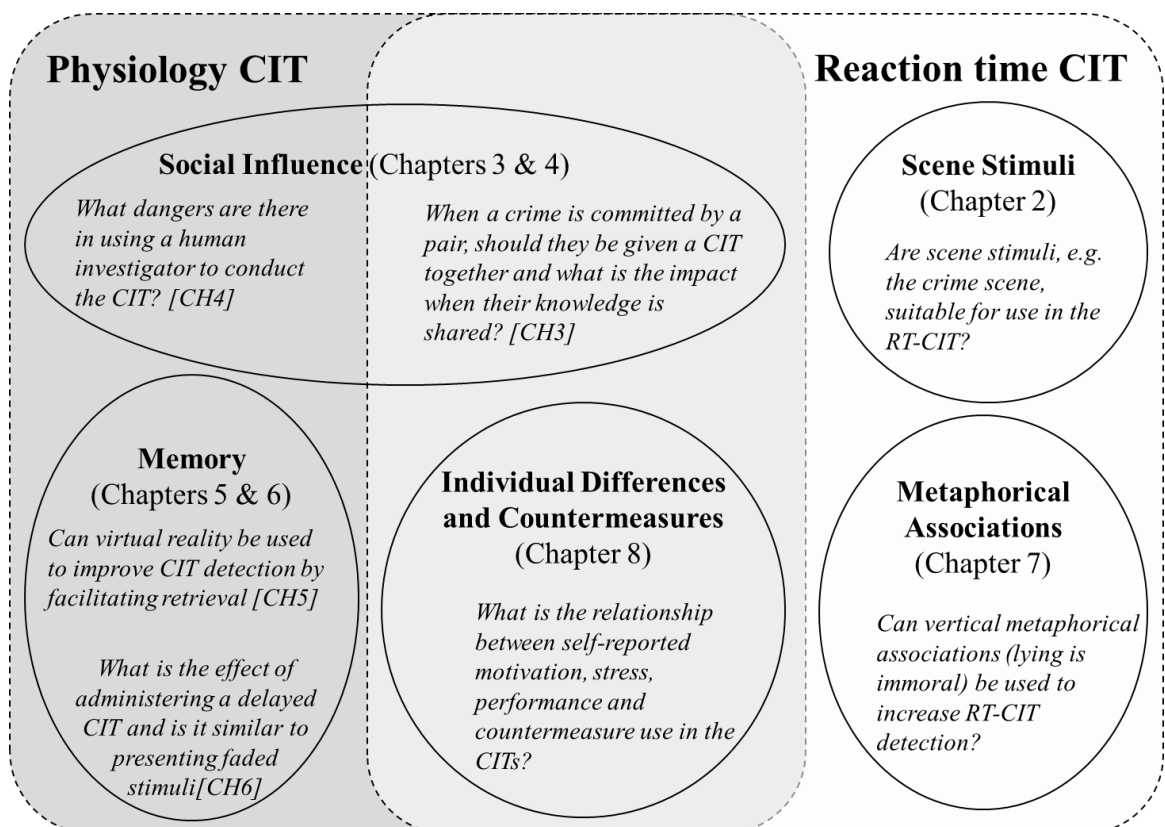


Figure 1.5. Overarching research questions explored in this thesis and which CIT paradigms were used.

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## CHAPTER 2

**Seen this scene?****Scene recognition in the reaction-time concealed information test****Abstract**

Detecting a suspect's recognition of a crime scene (e.g. a burgled room or a location visited for criminal activity) can be of great value during criminal investigations. Although it is established that the reaction-time Concealed Information Test (RT-CIT) can determine whether a suspect recognizes crime related *objects*, no research has tested whether this capability extends to the recognition of *scenes*. In Experiment 1, participants were given an autobiographic scene-based RT-CIT. In Experiment 2, participants watched a mock crime video before completing an RT-CIT which included both scenes and objects. In Experiment 3, participants completed an autobiographic scene-based RT-CIT, with half instructed to perform a physical countermeasure. Overall, the findings showed that an equivalent RT-CIT effect can be found with both scene and object stimuli and that RT-CITs may not be susceptible to physical countermeasure strategies thereby increasing its real-world applicability.

### Introduction

A key objective in forensic science is to link a culprit(s) to the crime scene (Fisher, 2004). DNA matching, tread mark or fingerprint analysis can be used to establish a connection between the culprit and the crime, however, such physical evidence, is not always available or adequately preserved (Peterson, Sommers, Baskin, & Johnson, 2010). In these situations, evidence of a connection between the culprit and crime often remain solely within the culprit's memory which the suspect will try to conceal. Information that a suspect may conceal recognition of include: i) Indoor or outdoor scenes of the crime, e.g., a room burgled; ii) Scenes which the culprit frequently visits to conduct criminal activity e.g., the transfer of illegal contraband; iii) Scenes where the culprit has hidden something or someone of interest e.g., a murder victim; iv) Scenes where the culprit has conducted reconnaissance for the purpose of planning criminal, military or terrorist activity; v) Protected facilities, e.g., government or military bases, accessed without authorization and; vi) Autobiographic scenes relating to locations that a person of interest denies recognizing e.g., schools, homes, workplaces. These are just some examples where detection of a culprit's concealed recognition of relevant scenes would be beneficial.

The Concealed Information Test (CIT) is a cognitive test designed to determine whether a suspect is concealing knowledge of hidden crime information that only the culprit would recognize (Ben-Shakhar & Elaad, 2003). Typically, the CIT determines a suspect's hidden recognition of crime details via analysis of their physiological response (typically skin conductance) to *crime* items (*probes*) compared with their responses to non-crime *control* stimuli, (*irrelevants*). Compared with control items, crime items elicit larger skin conductance responses, indicating



an increased level of orienting, taken to indicate recognition, to those stimuli (for a review see [Verschuere, Ben-Shakhar & Meijer, 2011](#)). This physiology-based CIT is well established and frequently applied in real-world cases, namely within the Japanese criminal justice system ([Osugi, 2011](#)).

An alternative, recently developed memory detection paradigm is the reaction time CIT (RT-CIT) which measures reaction times (RTs) instead of physiological responses. The RT-CIT relies on the idea that concealing knowledge of a crime requires inhibition of the truth leading to an overall slowing of responses made to crime-related items (see [Verschuere, Suchotzki, & Debey, 2014](#)). Compared to the physiological-CIT, the RT-CIT is less expensive, faster, easier to administer and analyze and does not require specialist training or equipment. The RT-CIT is an oddball task in which participants respond, using a keyboard, to a sequence of briefly presented stimuli. Each trial consists of the presentation of one of three types of stimulus: a *crime* (aka probe), a *control* (aka irrelevant), or a *target* item ([Figure 2.1](#)). Crime items are details that guilty a participant recognizes and control items are unrelated to the crime but are matched to crime items on relevant characteristics. For example, if the crime item was a set of bolt-cutters used to break a lock, control items would be equivalent tools such as a hacksaw or hammer. Participants are instructed to respond ‘No’ to indicate that they do not recognize either the crime or the control items. The third stimulus type are target items that the participant is shown before the test and are instructed to respond ‘Yes’ to and do not related to the crime information in question. Without these items, participants could simply respond ‘No’ on every trial without processing the stimuli.

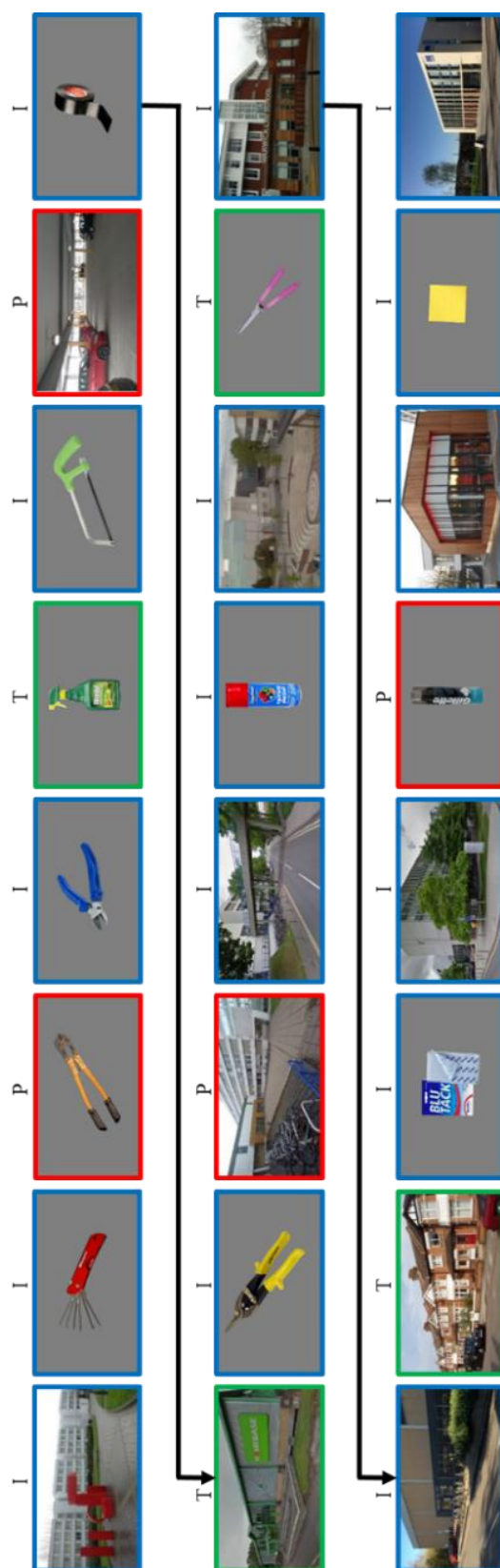


Figure 2.1. Example of one block of 24 images in an RT-CIT containing four crime items (red and 'P') each with four controls (blue and 'I') and one target (green and 'T').

Typically, guilty suspects are slower to respond ‘No’ (untruthfully), that they do not recognize a crime item, than they are to respond ‘No’ (truthfully), that they do not recognize a control item. It is proposed that this slowing reflects response inhibition experienced by participants whilst they resolve the conflict between recognizing an object yet reporting that they do not (Debey, Ridderinkhof, De Houwer, De Schryver, & Verschuere, 2015). Furthermore, this conflict sometimes results in an increased number of errors, for example, pressing ‘Yes’ to the crime items or ‘No’ to the target items (Suchotzki, Verschuere, Van Bockstaele, Ben-Shakhar, & Crombez, 2017). The target items serve no diagnostic role and are presented to ensure that participants process the stimuli and engage with the task. The RT-CIT can be as diagnostic as the physiological-based CIT, with a large effect size  $d = 1.05$ , and an  $AUC = .82$  [.77 - .87  $CI^{95\%}$ ], i.e. 82% chance that it can distinguish between guilty and innocent suspects (Suchotzki et al., 2017; Meijer et al., 2016;).

To date, RT-CIT studies have typically used word stimuli (Eom, Sohn, Park, Eum, & Sohn, 2016; Hu, Evans, Wu, Lee, & Fu, 2013; Kleinberg & Verschuere, 2016; Kleinberg & Verschuere, 2015; Noordraven & Verschuere, 2013; Seymour & Kerlin, 2008; Seymour, Seifert, Shafto, & Mosmann, 2000; Seymour & Fraynt, 2009; Verschuere, Kleinberg & Theocharidou, 2015; Verschuere, Crombez, Degrootte, & Rosseel, 2010; Visu-Petra, Miclea, & Visu-Petra, 2012; Visu-Petra, Varga, Miclea, & Visu-Petra, 2013; and Visu-Petra, Miclea, Buş, & Visu-Petra, 2014), with only a handful having used images. Moreover, those that have presented images have only used pictures of discrete objects that can be easily recognized and labeled (Visu-Petra, Jurje, Ciornei, & Visu-Petra, 2016; Varga, Visu-Petra, Miclea, & Visu-Petra, 2015; Suchotzki, Verschuere, Peth, Crombez, & Gamer, 2015). For

example, Visu-Petra and colleagues (2016) used images of objects (backpacks, watercolors, pencils, and erasers) to test the effectiveness of the RT-CIT in children. In studying the effects of emotional valence, social factors and individual differences in the RT-CIT, another study presented pictures of objects (e.g., ‘memory sticks’, ‘laptop bag’, ‘mobile phone’, ‘wireless mouse’ and an ‘agenda’) and found that responses to crime and control items differed with a large effect size, Cohen’s  $d = 1.05$  (Varga et al., 2015). Similarly, another experiment used images of objects (e.g. ‘50 euro note’, ‘laptops’, ‘CDs’, ‘markers’, ‘water crates’, ‘suitcase’ and so on) and again found that crime and control items differed with a large effect size,  $d = 1.24$  (Suchotzki et al., 2015). Clearly, images of objects can be used effectively in the RT-CIT to detect deception. However, the detecting the concealed recognition of scenes might greatly assist investigations by linking the suspect to a crime scene rather than an object. The RT-CIT is one potential tool for achieving this, however, to the author’s knowledge the effectiveness of the RT-CIT for scene recognition has not been examined. However, this is not to say that scene stimuli have not been used in physiological-based CITs in both research and the field for example a recent study used scene stimuli in their CIT (Norman, Wade, Williams & Watson, 2020).

Whilst there is extensive research on object recognition, (Ganis & Kutas, 2003) the nature of scene memory and its underlying mechanisms are under debate (Oliva & Torralba, 2006; Behrmann & Plaut, 2013). However, it is clear that scenes differ from objects in terms of processing, encoding, and recognition, all of which could change their effectiveness within the RT-CIT (Behrmann & Plaut, 2013). For example, memory for scenes is remarkably robust with participants able to encode and recall thousands of scenes that are previously novel to them (Standing, 1973; Standing, Conezio, & Haber, 1970; Kent, Lamberts, & Patton, 2018). Furthermore,

whereas objects can be encoded in a single exposure, whole scenes are encoded into memory over several glances building the memory incrementally over time (Melcher, 2006). The requirement of incremental processing makes scene detection especially difficult within the RT-CIT if there has been insufficient time for full scene encoding during the crime. Another key object-scene difference is that scenes usually contain a complex mixture of objects and features that could capture attention in differing ways. Some attention-grabbing objects/features (e.g., people or objects in the scene) might not be related to the crime thus rendering those scene stimuli undiagnostic. Finally, compared to objects, scenes cannot always be easily semantically labeled, with those that can, e.g., a 'beach', being more familiar than those that cannot. Relatedly, scene recognition is possible even without being able to identify exactly what or where the scene is; Recognition Without Identification (Cleary & Reyes, 2009). RTs to scene stimuli are seldom compared with objects (Ganis & Kutas, 2003), despite being an important factor when considering the use of scenes in the CIT. Global scene information is believed to be processed rapidly and parallel to local object processing and requires fewer attentional resources than objects (Munneke, Brentari, & Peelen, 2013) with scene color processed very rapidly (~50ms, Wichmann, Sharpe & Gegenfurtner, 2002). This ability is potentially attributable to the Parahippocampal Place Area that appears to respond only to scenes and not to objects (Oliva & Torralba, 2006). This rapid initial understanding of a scene is called 'scene gist' and is achieved very quickly (20ms, Oliva & Torralba, 2006).

Testing whether a suspect recognizes a scene can be beneficial and the RT-CIT could be an appropriate test for doing so. However, as described there are differences in how scene and object stimuli are processed and the possible effects

this can have on response times and detection in the RT-CIT is currently untested. In the current study, Experiment 1 established whether scenes produce a comparable RT-CIT effect to those found for object stimuli in the literature. Participants completed an RT-CIT in which they were instructed to conceal knowledge of autobiographic University campus scenes. Experiment 2 compared scenes and objects by having participants watched a mock crime video before completing an RT-CIT that contained both object and scene stimuli. Experiment 3 tested the susceptibility of scene-based RT-CITs to a physical countermeasure strategy aimed at slowing response to control items.

### Experiment 1: RT-CIT with scene stimuli

Previous work has demonstrated that images of objects and scenes are processed, encoded and recognized differently and any of these factors could influence the effectiveness of scene stimuli in the RT-CIT. In Experiment 1, a scene-based RT-CIT was tested to determine whether it produced a RT-CIT effect similar to that found for object-based RT-CITs. Using autobiographic scenes of the participants' University campus, a scene-based RT-CIT was given to participants who were instructed to conceal recognition of their University.

#### Method

##### Participants

Previous object image-based RT-CIT experiments have shown large CIT effect sizes ranging from  $d = 1.05$  to  $1.24$  (Suchotzki et al., 2015; Varga et al., 2015; and Visu-Petra et al., 2016). Given this was the first reported scene-based RT-CIT, a smaller, but still large, effect size was estimated<sup>1</sup>. A power analysis using G\*Power (Faul, Erdfelder, Lang, & Buchner, 2007), with an effect size of  $d = 0.8$ , and  $\alpha = 0.05$  for a single group, suggested that 23 subjects would be sufficient for a power of 0.95. Thirty-six participants (25 women), aged between 18-32 years ( $Mean = 20.4$ ,  $SD = 2.8$ ) were recruited through a University of Warwick online participant panel. Participants received £3 payment for taking part in the 30-minute testing session.

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<sup>1</sup> On reflection our initial estimation of an RT-CIT effect size of  $d = 0.8$  for scene stimuli may not have been optimal given our review of the literature suggested that the effect size for scene could be smaller than objects. Reassuringly however, a post-hoc power analysis, computed using the same parameters as above but using the resulting effect size found in this Experiment, estimated that a sample size of nine was enough.

### **Materials**

The image stimuli were photographs of scenes that typically contained landscapes, buildings, and other structures. The autobiographic images ('crime' items), were images of various scenes of the participants' university campus. For each crime item, four matched control scene stimuli were sourced using Google's Reverse Image Search function with the crime items as reference images. This resulted in a selection of structurally similar scenes based on low-level local features such as color, contrast/brightness, texture and shape at specific parts of the images (Chechik, Shalit, Sharma, & Bengio, 2009; Horváth, 2015). From this selection, we chose four control images based on their content similarity to the crime images. This allowed for the matching of appropriate control items for all crime scenes. In addition to the crime and control stimuli, five images of another University were used as target items. At the start of the study participants chose five scenes of their university campus, out of a selection of twenty, that they felt were most familiar to them which became the crime items. This was to ensure optimal encoding of these items prior to testing more ecologically valid scenarios. All images were open source, cropped to remove potential noise (e.g., people), were resampled to 1366 x 768 pixels and presented full-screen on a 21" LCD monitor, 16:9 aspect ratio at a resolution of 1920 x 1080 pixels (Figure 2.2). Participants sat approximately 40cm from the screen with the center of the screen at approximately eye level.



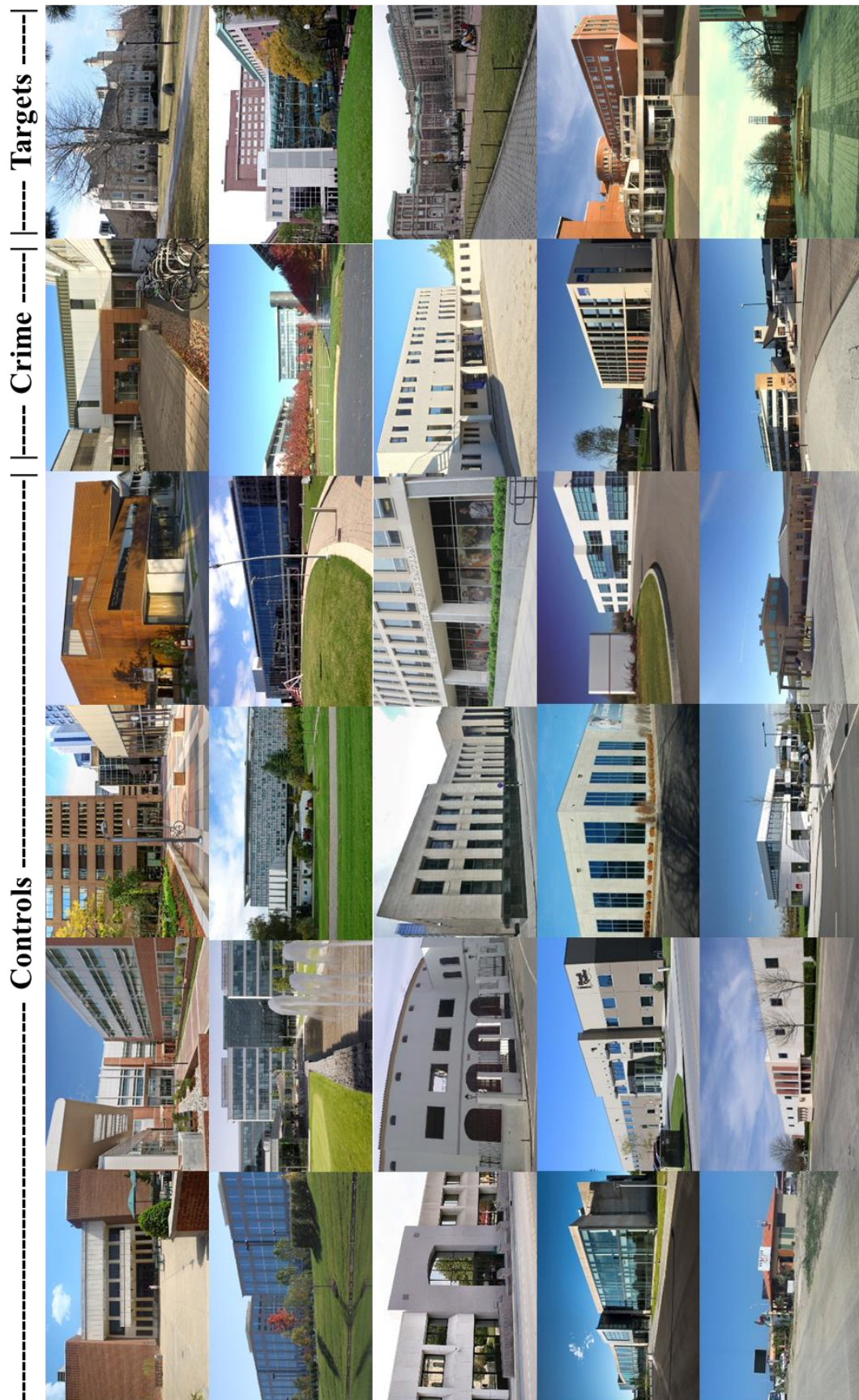


Figure 2.2. Examples of control, crime and target scenes used in Experiment 1.

### The CIT

The RT-CIT consisted of 450 images with 30 images (one block) repeated 15 times. Each block of 30 images contained five CITs and each CIT consisted of six images: a crime item, a target, and four control items. There was a short break of 3000ms after each block and a longer break of 30 seconds after every three blocks. The image duration was 800ms with a randomly selected inter-stimulus interval of either 500, 750 or 1500ms.<sup>2</sup> Items within each block were presented sequentially in a random order with the constraint that two crime items could not occur consecutively. The targets were randomly presented within each block and did not change irrespective of what crime items were selected by participants. Target items were not analysed as they were only used to ensure participant engagement with the stimuli. The data from participants with error rates (i.e., pressing “Yes” to a crime item) above 50% were removed from further analysis as it is unlikely that they were following the task instructions. Responses faster than 200ms or slower than 800ms were removed, as recommended in the literature ([Verschuere et al., 2015](#)). Incorrect responses were also removed from the RT analysis.

**Procedure.** Participants completed the experiment in a computer lab in two groups of 18. Participants were provided with an overview of the procedure, given the opportunity to ask questions and provided consent and demographic information. They were informed of their right to withdraw at any point without penalty or reason. Participants were then asked to imagine that they “*are an undercover spy from*

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<sup>2</sup> Due to a technical error, the first half of the participants saw an extended inter-stimuli interval of 1000, 1500 or 3000ms (instead of 500, 750 or 1500ms). However, ISI length (intended vs. extended) did not interact with control and crime item RTs,  $F(1, 34) = 3.363$ ,  $p = .075$ , or % error rates  $F(1, 34) = .114$ ,  $p = .738$ , and therefore results were collapsed over ISI length.

*Warwick University and have infiltrated New York University to steal their latest research. New York University Security suspects a mole and are therefore requiring all staff to sit a 'lie detection test.' Their 'lie detection test' assumes that spies will be slower to recognise and make more mistakes when they respond to images of New York University. They are also hoping to catch spies that accidentally respond "Yes" to images of Warwick University who they believe are the prime suspects."*

Participants were then given five images of 'New York University' and told to memorise these to help them beat the lie detection test. Participants were then told that *"during the 'Lie Detection Test' you will be shown a series of items of scenes. Many of these items will be unfamiliar to you except the ones relating to Warwick University (which you must keep secret) and the scenes of New York University which you have just memorised. Each image will appear for around 1 second with less than a second gap between them. Using the keyboard, please respond to these images as fast as you can making as few errors as possible! The question to consider for each image is 'Do you recognise this scene?'"*

Participants were instructed to press the LEFT KEY for "Yes" responses, i.e. New York University Images (targets), and the RIGHT KEY for "No" i.e. University of Warwick (crime items) and any other images (control items). Participants were given the opportunity to ask any questions before completing a practice test consisting of two blocks of trials (60 images). During the practice stage only, if the response was incorrect e.g. a "Yes" response to a crime item, the words "Wrong" were displayed until the start of the next trial. If a response time exceeded 800ms the words "Too Slow" were displayed until the start of the next trial. Participants were aware that this information would not be provided following the practice stage.

Participants then completed the main test followed by debriefing. All studies were approved by the departmental ethics committee at the authors' institution.

## Results

**Reaction Times.** No participant's data were removed due to error rates above 50%. Including target items, trials that exceeded the response deadline (1.3%), were faster than 200ms (0.19%) and incorrect trials (3.61%) were removed from the analysis (incorrect responses are used for the error analysis). Mean correct RTs were calculated for crime and control items for each participant and overall means are shown in [Figure 2.3](#). A paired t-test on Item Type revealed that RTs were significantly slower for crime items compared to the control items,  $t(35) = 8.87$ ,  $p < .001$ ,  $d = 1.48$ , ( $MD = 29.4$ ).

**Error Rates.** Error rates were low overall ( $Mean = 1.34\%$ ,  $SD = 2.35$  and  $Mean = 0.97\%$ ,  $SD = 2.47$  for crime and control items respectively) and did not differ significantly,  $t(35) = 1.26$ ,  $p = .215$ ,  $d = .279$ , ( $MD = .926$ ).

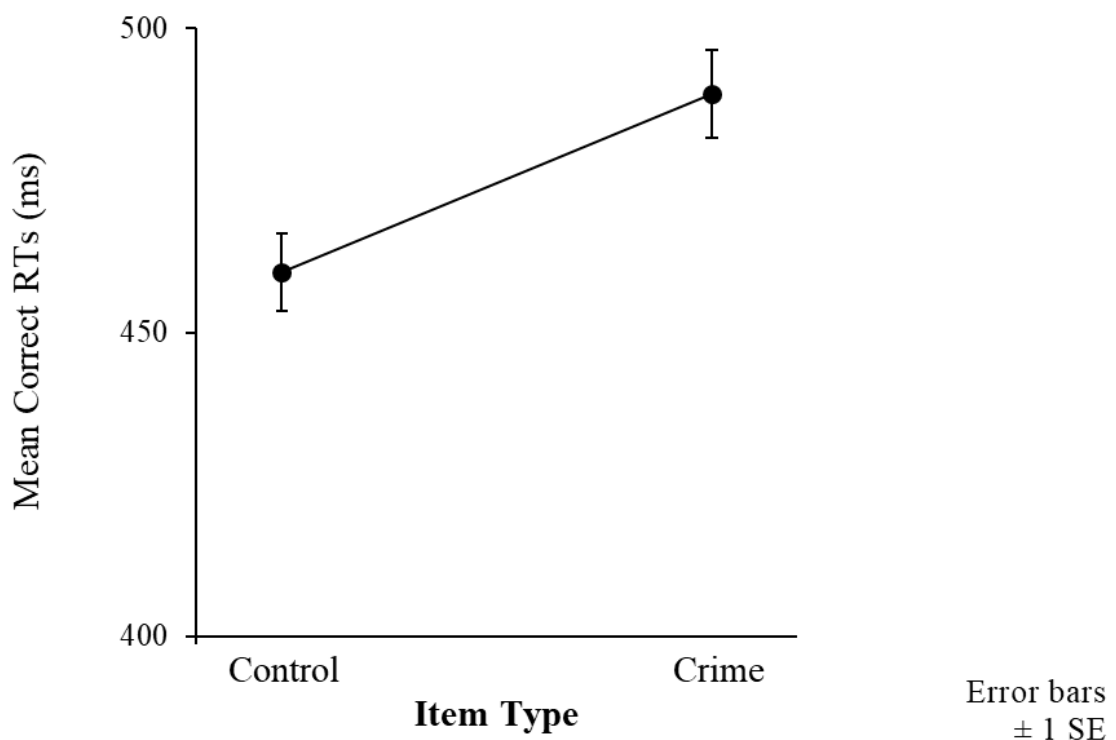


Figure 2.3. Experiment 1. Mean correct RTs as a function of Item Type.

### Signal Detection Analysis

To assess the efficiency of detection, signal detection analysis was used to determine the degree of separation between the participants in our experiment who were considered 'guilty' and an equivalent innocent group. First, responses to each trial from each guilty participant were converted to within-subjects standardised scores (z-scores) (Ben-Shakhar, 1985). Given no innocent participants were tested, data for innocent participants were simulated by the standard method used in the CIT literature (e.g. Carmel, Dayan, Naveh, Raveh, & Ben-Shakhar, 2003; Visu-Petra et al, 2013; and Meijer, Smulders, Johnston, & Merckelbach, 2007). This approach assumes that innocent participants, not knowledgeable about the crime item, respond in the same manner to all items. Therefore, the procedure for simulating innocent participant data involves drawing random RTs from a standard normal distribution. This is conducted for each trial with one trial in five then randomly chosen to represent the simulated crime item. Once calculated for each participant, an ROC was generated to approximate the signal detection using within-subject scored RT-CIT effect (crime minus control item) for the 'guilty' group and for the normalized simulated 'innocent' group. ROCs are based on a comparison of two detection score distributions, where detection score of guilty was defined as the mean normalized difference between crime and control items and the detection score of innocents was similarly defined but using the simulated crime and control responses.

As shown in Figure 2.4, the curve is close to the upper left-hand corner of the ROC, which indicates a high overall accuracy (Zweig & Campbell, 1993). The area under this curve (*AUC*) allows an objective measure of the accuracy trade-off between the test sensitivity and specificity. An  $AUC = 0.5$  suggests no discrimination (chance level), 0.7-0.8 is considered fair, 0.8-0.9 is considered excellent, and 0.9+ is

considered outstanding (Hosmer Jr, Lemeshow, & Sturdivant, 2013). In our scene-based RT-CIT the  $AUC = .919$  indicating an outstanding diagnostic test (Figure 2.4) and meshed with the large group level effect size  $d = 1.93$ . Note that this effect size is the between-subjects effect size for guilty versus innocent participants as opposed to the within-subject mean RT difference between crime and control items for guilty participants.

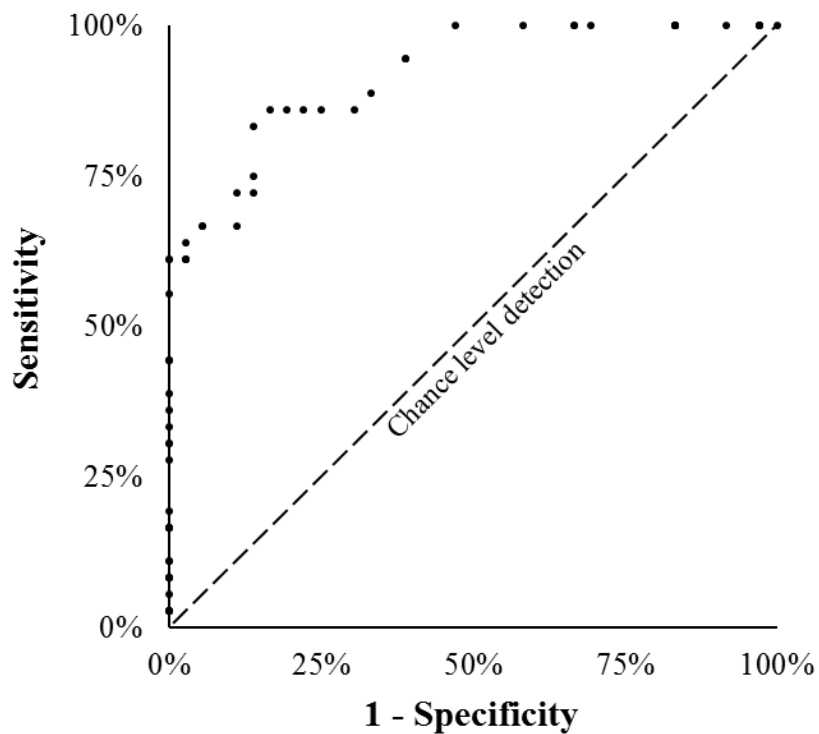


Figure 2.4. Experiment 1. Signal detection curve (ROC) showing the detection sensitivity and specificity between guilty and simulated innocent participants



## Discussion

The finding from this experiment suggests that scene stimuli can be as effective as object picture stimuli when used within an RT-CIT. To our knowledge, this is the first attempt to experimentally test scene stimuli in the RT-CIT, however, there are some limitations. First, the scenes used represented autobiographic details which would rarely be used in a field setting. Second, participants were given the choice of five out of a set of twenty scenes to act as the crime item. Clearly this limits the generalizability of these initial findings as, in a field CITs, participants would not have this choice. This compromise on ecological validity was chosen to ensure maximal encoding of these scenes had taken place to allow for initial testing of the scene-based RT-CIT under optimal conditions.

Despite a large effect based on RT differences, there was no CIT effect for error rates. Some studies have found differences in error rates for crime and control items however this is not always the case ([Visu-Petra et al, 2016](#); [Hu et al, 2013](#); [Noordraen & Verschuere, 2015](#)). In Experiment 1, the lack of error rate CIT effect could be caused by the relatively low overall error rates obtained in our study (approximately 3.6%). Alternatively, the lack of an error rate effect might be due to our use of scene stimuli; further study could clarify this. Finally, although our findings suggest that scene stimuli allow for a diagnostic RT-CIT, they do not directly tell us whether there is a difference between scene and object-based RT-CITs. Accordingly, in Experiment 2 this is investigated by presenting participants with a mock crime video (rather than relying on autobiographical memory) containing both scene and object stimuli allowing a direct comparison between the two.

### Experiment 2: Scenes vs. objects in RT-CITs

Experiment 1 validated the use of scenes as stimuli in the RT-CIT. However, the scene images were autobiographic in nature and scene stimuli were not directly compared with object stimuli. To address these issues, in Experiment 2, participants watched a mock crime video before completing an RT-CIT that contained both object and scene images. The use of a mock crime video technique not only allowed a mixture of object and scene crime items to be tested but also allowed scene stimuli to be tested in a more realistic context, thereby increasing generalizability.

#### Method

##### Participants

Initially the number of participants from Experiment 1 was simply increased for Experiment 2 to account for the reduced reliability as a result of halving the number of trials to account for the additional within subject condition i.e. object stimuli. Furthermore, due to use of an undergraduate participant pool for course credit, control over the exact number of participants was limited. Forty-four participants (38 women, aged 18-21, *Mean* = 18.8, *SD* = 0.8) were recruited from an Undergraduate Psychology course and took part in the 30-minute testing session in return for course credit<sup>3</sup>.

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<sup>3</sup> Given no previous literature on a possible scene-object RT-CIT difference the authors referred to a previous study which, during a post-hoc analysis, found no significant difference between object and scene stimuli in the physiological CIT (Norman et al., 2020). Analysis of that data revealed no significant interaction between Item (Crime vs Control) and Stimuli (Object vs Scene) and a medium effect size of,  $\eta_p^2 = .046$ . A post-hoc power analysis using G\*Power (Faul et al., 2007), the effect size above, and  $\alpha = 0.05$  for a repeated measures ANOVA, suggested that 46 subjects would be sufficient for a power of 0.95.



### Materials

Instead of the autobiographic scenes of the University campus used in Experiment 1, a three-minute, 1<sup>st</sup> person perspective mock crime video was shown to participants (Figure 2.5). In the following text-based description of the video *italics* indicate crime items. Participants (observing from the perspective of the thief) identified a locked bike outside the *Humanities building entrance*. The participants covered up a nearby CCTV camera using *shaving foam* and then used *bolt cutters* to break the bike lock. The culprit then met an accomplice in a multi-story *carpark* to hand over the bike for cash. Four matched control items were selected for each crime item (Figure 2.6). For Target items (highlighted), a false alibi was constructed: “*It wasn’t me who committed that crime as I was with my friend at his home gardening all day. We only left his house to buy some garden clippers and weed killer from a nearby DIY store.*”. Therefore, in total there were two object crime items and two scene crime items each with four controls and one target. The remaining experimental set up was the same as Experiment 1.



Figure 2.5. Key events in the 1<sup>st</sup> person-perspective mock crime video that guilty suspects view (*crime items in italics*).

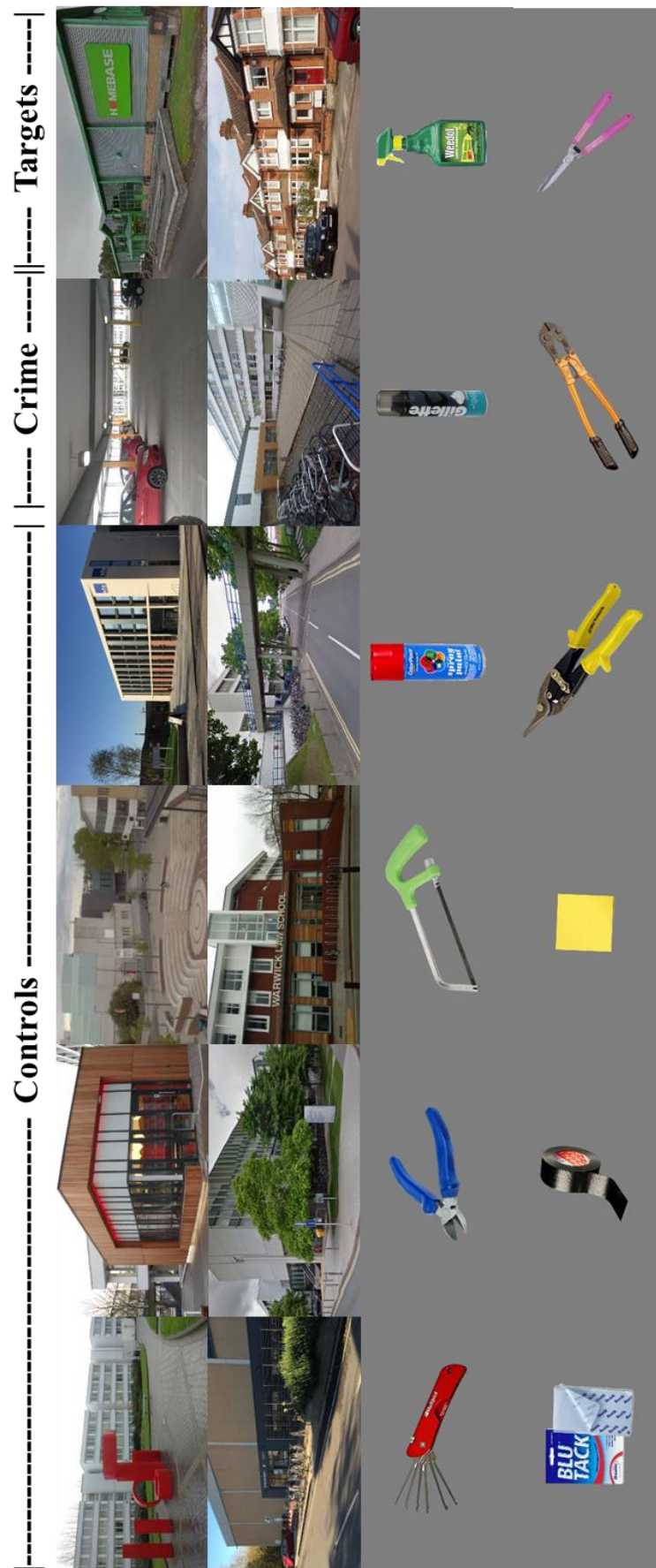


Figure 2.6. All scene and object images used in Experiment 2.

### The CIT

The RT-CIT of Experiment 1 was used except that there were 360 images were presented in 15 blocks of 24 images. Each block consisted of four CITs, (two object CITs and two scene CITs), with each CIT containing a crime item, target, and four control images (Figure 2.6). Image order was randomised with the exception that crime images were always preceded by control images and each block always started with a control item.

### Procedure

Participants were provided with an overview of the study procedure, given the opportunity to ask questions and then provided consent and demographic information. Participants were informed of their right to withdraw at any point without penalty or reason. Participants were then told *“You’ll now watch a three minute, 1st person perspective, mock crime video, of a thief, (you!) stealing a bicycle from outside the humanities building on campus. It’s really important you pay attention throughout and really try to imagine yourself as the person whose perspective you’re seeing in the video. There will also be a memory test at the end.”* Participants then put on headphones and watched the mock crime video. Following the video, participants were asked to *“Now imagine you have been contacted by the local police station and have been informed that you are now a potential suspect in a recent crime. They explain that during their investigation they would like to administer a lie detection test to all potential suspects to help narrow down their investigation. The lie detection test will use the crime images below which you should now recognize from the video”*. Participants were then shown the four crime images that would be used in the test to ensure sufficient encoding (note this would

not be appropriate in an applied setting however was done to ensure optimal encoding).

Participants were then told, *“You have asked your good friend to be a false alibi for the time of the events and you have told the police this alibi story...”*

Participants were then given their false alibi and four images related to it to remember. Participants were then told: *“During the ‘Lie Detection Test’ you will be shown a series of items consisting of objects and scenes. Many of these items will be unfamiliar to you except the ones relating to the crime you just ‘committed’ (in the video) and the Alibi items you have just memorised. Each image will appear for around 1 second with less than a second gap between them. Using the keyboard, please respond to these images as fast as you can making as few errors as possible! The question to bear in mind for every image is: “Do you recognise this item?”.*

Participants were instructed to press the LEFT KEY for “Yes” responses, that is, False Alibi Images (targets), and the RIGHT KEY for “No”, that is, Mock Crime Images (crime items) and any other random Images (control items). The remaining instructions were the same as in Experiment 1 until after the RT-CIT when participants completed a short memory check and were asked to rate how immersive they found the mock crime video on a Likert scale of 1 (not immersive) to 6 (highly immersive). Finally, participants were debriefed.

## Results

No participant data were removed from the analysis due to error rates above 50%. Including target items, trials that exceeded the response deadline (1.6%), were faster than 200ms (0.36%) and incorrect responses (5.0%) were removed from the analysis (Incorrect responses were used for the error analysis).

**Manipulation Checks.** Participants rated the first-person perspective crime video as immersive, with a mean rating of 4.2 out of 6 ( $SD = 0.93$ ). When asked to identify the correct crime items, 40 out of the 44 (91%) participants correctly recalled all crime-relevant items with the other four participants forgetting one item each.

**Reaction Times.** A 2 (Image Type: Object vs Scene)  $\times$  2 (Item Type: Control vs. Crime) within-subjects ANOVA on the mean correct RTs revealed a significant main effect of Image type,  $F(1, 43) = 14.8, p < .001, MSE = 10031, \eta_p^2 = .256$ , (RT-CIT effect was  $d = .784$  collapsed over Image type) and of Item type,  $F(1, 43) = 26.5, p < .001, MSE = 16885, \eta_p^2 = .381$ . As shown in [Figure 2.7](#), RTs were slower overall with scene stimuli than with object stimuli and were slower on crime trials than on control stimulus trials. The Image type  $\times$  Item type interaction type was not significant,  $F(1, 43) = .102, p = .751, MSE = 41.1, \eta_p^2 = .002$ .



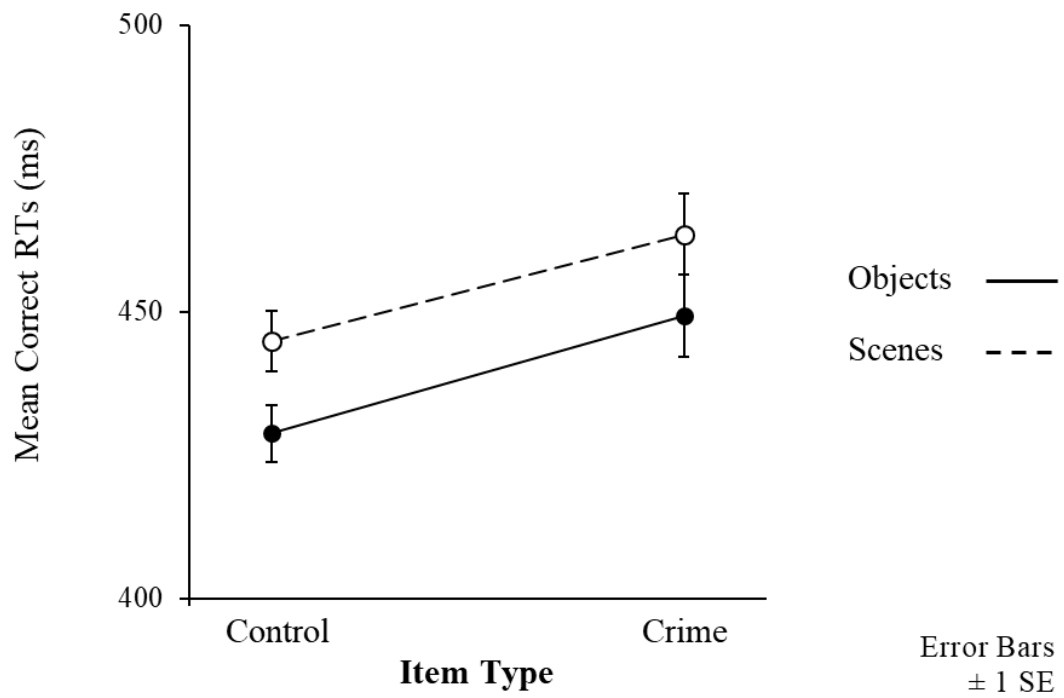


Figure 2.7. Experiment 2 - Mean correct RTs as a function of Item Type and Image Type.

**Bayesian Analysis.** Where frequentist analysis reveals a non-significant difference, the Bayes factor  $BF_{01}$  is sometimes reported to quantify the degree to which the data support the null hypothesis (Wagenmakers et al, 2018). Therefore, to further assess the interaction between Image type and Item type reported above, the RT-CIT effect (the difference between the crime and control item) was compared for both scene and object stimuli using a Bayes t-test with JASP software (JASP Team, 2018). With a default Cauchy prior width of 0.7 this revealed a  $BF_{01}$  of 5.8, implying ‘substantial evidence for the null hypothesis’ (Jefferys, 1961). This suggests that scenes and objects produce an equivalent CIT effect.

**Errors.** A 2 (Image type: object vs scene)  $\times$  2 (Item type: Control item vs. crime item) within-subjects ANOVA on mean error rates revealed a significant main effect of Item type,  $F(1, 43) = 6.28, p = .016, MSE = 65.2, \eta_p^2 = .127$ , but not for Image type,  $F(1, 43) = .412, p = .524, MSE = 11.3, \eta_p^2 = .009$ . As shown in Figure

2.8, error rates were higher for crime trials than for control stimulus trials but there was no difference between scene and object stimuli. The Image type  $\times$  Item type interaction was not significant,  $F(1, 43) = .166, p = .686, MSE = 8.39, \eta_p^2 = .004$ . A Bayes t-test calculated using the crime-control item differences for objects and scenes revealed a  $BF_{01}$  of 5.7, implying ‘substantial evidence for the null hypothesis’.

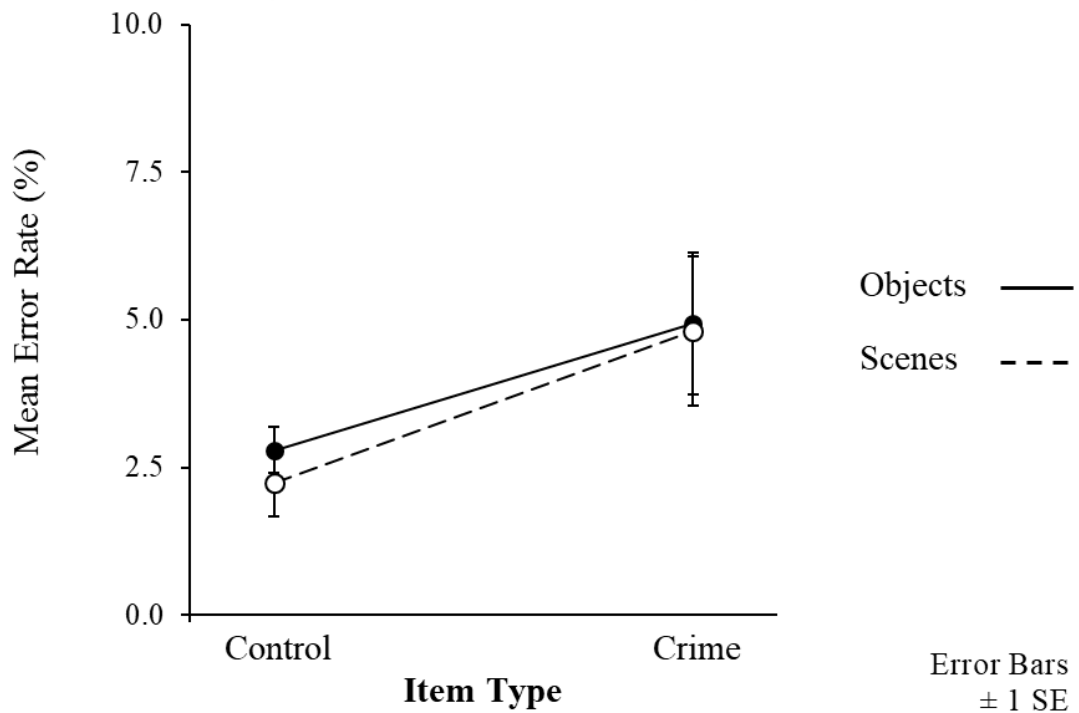


Figure 2.8. Experiment 2 - Mean % errors as a function of Item Type and Image Type.

### Signal Detection Analysis

Using the same procedure as Experiment 1, a signal detection analysis was conducted for all participants using their RT responses for both scene,  $AUC = .696$  and  $d = .728$  and object stimuli,  $AUC = .709$  and  $d = .791$  (Figure 2.9). Note that collapsed over Image type  $AUC = .746$  and  $d = 1.01$ .



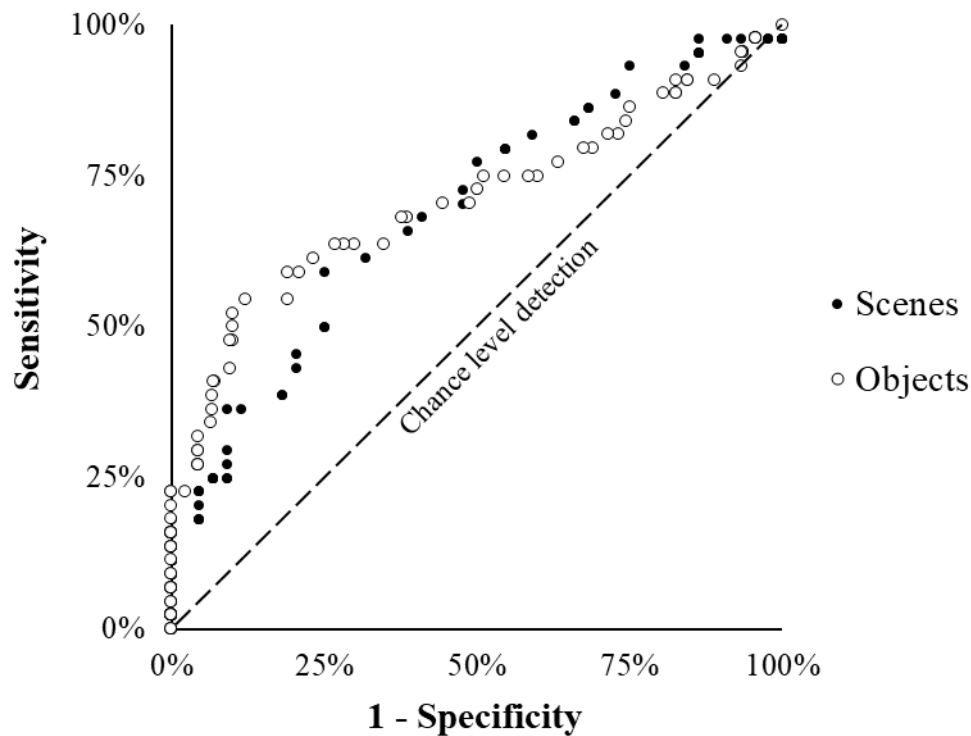


Figure 2.9. Experiment 2 - Signal detection curve (ROC) showing the detection sensitivity and specificity between guilty and simulated innocent participants

### Discussion

In Experiment 2, both scene and object stimuli were used from a mock crime video thereby allowing a direct contrast between stimulus type and removing the reliance on autobiographic memory as used in Experiment 1. The main finding was that, once again, scene stimuli successfully elicited an RT-CIT effect. Moreover, a Bayesian analysis indicated that scenes and objects were equivalent in terms of producing crime-control item RT differences. Signal detection analysis based on the RT data revealed a lower *AUC* in Experiment 2 compared to Experiment 1, likely due to both the smaller number of crime items used in Experiment 2 (four instead of five) (Meijer et al., 2014) and the use of the mock crime stimuli compared to autobiographic. A secondary finding was that participants responded more slowly to scenes than to objects. This suggests that scenes may be more cognitively demanding to process, perhaps because they are made up of multiple objects and have a

generally higher complexity than pictures of isolated, single objects. In any case, the finding of an equivalent crime-control difference for pictures of objects and scenes suggests that this overall difference between scenes and objects does not impair the effectiveness of the test.

In contrast to Experiment 1, the RT-CIT effect was found for both RTs and error rates. This may be due to the higher number of errors in Experiment 2 compared to Experiment 1 (3.6% and 5.0% respectively,  $p = .042$ ). Thus, the overall difficulty of the task may determine whether or not an RT-CIT effect is expressed in error rates as well as in RT measures. Either way, these findings indicate that although errors can be useful in detecting ‘guilty’ participants, they may be a less reliable measure than RT-based data. In Experiment 3 we test the robustness of the RT-CIT to countermeasures.

This experiment sought to determine whether there were any differences in the RT-CIT effect between object and scene stimuli under optimal conditions. Therefore, to reduce the chance of participants not adequately encoding the mock crime items they were briefly reminded of the key crime information i.e. the crime items after the mock crime video. Of course, this would not be possible in a real CIT as it would compromise innocent, unknowledgeable participants.

Overall, the first-person perspective mock crime video was rated as immersive and resulted in 91% of participants being able to recall all crime items, which consisted of two scenes and two objects. However, the use of the mock crime video in this experiment, although practical, is unlikely to mimic scene encoding in the real world given the scale and encoding duration. It is possible that any differences between object and scenes become more apparent when encoding is done in a real-world crime. Nevertheless, this was indirectly examined in a previous study

where participants did encoding both objects and scene in the real-world before undergoing a physiological-based CIT – this also revealed no significant difference in the CIT effect ([Norman et al., 2020](#)). However, in both the current study and the one by Norman and colleagues, no delay between encoding and testing were introduced. These experimental compromises clearly limit the ecological validity of this work and therefore further work would be advisable.

Finally, although this experiment did not reveal any significant difference in the RT-CIT effect between object and scene stimuli it is worth considering potential confounding variables. Scenes and objects can differ in saliency and saliency is known to modulation the CIT. Previous work (e.g., [Kleinberg and Verschuere, 2015](#), see also [Klein Selle, Verschuere, Kindt, Meijer, & Ben-Shakhar, 2017](#); [Jokinen, Santtila, Ravaja & Puttonen, 2006](#)) has shown that items with higher personal salience (e.g., country of origin or birthday) produce a larger reaction time CIT effect than less personally salient stimuli (e.g., favorite color or animal). Therefore, it is possible that scene stimuli may in fact result in a differing RT-CIT effect to objects but that this effect is not seen in this study due to differences in item-specific saliency which was not control in this work. Further work controlling for this possible modulating factor would be beneficial.

### **Experiment 3: The effect of countermeasures on the RT-CIT**

Experiments 1 and 2 showed that scene stimuli are no different to object stimuli in their ability to generate a CIT effect. However, in both experiments participants were not instructed to use any form of countermeasure strategy (a strategy to try to fool the test and elicit a false negative result). One would expect guilty suspects in the real world to attempt to use some form of countermeasure strategy to avoid detection and, arguably, this could be simple to perform in an RT deception test (Gronau, Ben-Shakhar, & Cohen, 2005). Steps to mitigate against countermeasure strategies are therefore frequently used in standard RT-CIT procedures. For example, a response deadline of 800ms is used to prevent participants from intentionally delaying responses to control items and therefore negating the CIT-effect. Furthermore, target items that require a different response (“Yes”) to crime and control items are used to ensure that participants are engaging with each stimulus as presented. If they were not, then this would yield a high error rate suggesting that the participant is either not paying attention or attempting some form of countermeasure.

A handful of studies have consider the effects of countermeasures on deception tasks similar to the RT-CIT. Ganis and colleagues (2011) gave twenty-six participants an fMRI-based RT-CIT, using word stimuli, and instructed them to covertly move the left index, middle finger, and toe to three out of the four control items during the CIT. The idea was that this might increase the RTs for control items and thus reduce the difference between the crime and control stimuli neutralizing the RT-CIT effect. The countermeasures were effective in increasing RTs to control items compared with crime items resulting in a negative RT-CIT effect ( $MD = -313\text{ms}$ ,  $SE = 74$ ). Compared to the control group ( $MD = 60\text{ms}$ ,  $SE = 54$ ) this suggested a large

countermeasure effect size,  $d = 1.73$  for the RT differences with a similar result found for the f-MRI measure,  $\eta_p^2 = 0.94$ .

In another study, Huntjens, Verschere, and McNally (2012) presented a word-based autobiographic RT-CIT to a control group, countermeasure-instructed (“*do not respond any faster or slower to the crime items*”) group, and a dissociative identity disorder patient group ( $n = 27, 23$  and  $11$  respectively). They found no difference between the control and countermeasure group, who still showed a crime-control item difference ( $d = .48$ ). However, in Huntjens and colleagues' (2012) study, participants were simply instructed not to respond any faster or slower to crime items which, without further instruction is unlikely to have been a sufficient countermeasure strategy.

An ERP-based CIT, using word stimuli (Mertens & Allen, 2008) tested seventy-nine participants across five conditions: control, innocent, and three countermeasure instructed groups. Countermeasure instructed groups were given directions to: “*think about being slapped by a bully*” (Group 1), “*apply pressure to the toe*” (Group 2) and “*think about being slapped by a bully after the first distracter, tightening of the sphincter muscle after the second, distracter, applying pressure to toes after the third distracter, and not responding at all to the fourth distracter*” (Group 3). Although this study found countermeasure differences for EPR amplitude and latency, the behavioral RT data only showed a countermeasure effect for Group 3. Note however that all other groups still showed a significant RT-CIT effect.

In another ERP-based CIT study, with a reaction time measure and also using word stimuli (Rosenfeld, Soskins, Bosh & Ryan, 2004), thirty-three participants were asked to perform covert tasks when control items were presented. The covert act were i) pressing the left forefinger, ii) pressing the left middle finger, iii) wiggling the

big toe in the left shoe, iv) wiggling the big toe in the right shoe, and v) imagining the experimenter slapping the participant. Compared to a control group where 91% of participants were correctly classified based on their RTs, only 45% of the countermeasure instructed group were demonstrating a significant countermeasure effect. Rosenfeld and colleagues found a significant difference between RT differences (crime minus control) for their guilty (no countermeasure) and countermeasure group,  $t(10) = 2.19, p < .05$ , suggesting a large countermeasure effect size  $d = .932$ .

Finally, using an Autobiographical Implicit Association Test (aIAT), one study found that 39-78% of its eighteen guilty participants were able to remain undetected by being informed on how the aIAT works and instructing participants to slow down in the confession-true task ([Verschuere, Prati & Houwer, 2009](#)). Other the three experiments, participants given countermeasure instructions could significantly lower their test score to appear innocent (average countermeasure  $d = .98$ ). The studies described suggest that countermeasures can be effective in reducing detection, however few studies have tested the impact of countermeasures in RT-CIT tasks that do not also use ERPs or fMRI (see [Suchotzki et al., 2017](#), for a small meta-analysis of these). Furthermore, none of the above studies have tested the susceptibility of scene stimuli to countermeasures.

Accordingly, in Experiment 3, a physical countermeasure strategy was tested in a scene-based RT-CIT. The most obvious approach to reduce the RT-CIT effect, i.e. the difference in RT's between crime and control items, is to slow responses to the irrelevant items. As described there are difference approaches to this broadly categorized as either mental or physical countermeasure strategies. In this experiment we chose a simple and easy to perform physical countermeasure that requires little

practice - press upon or wiggle a toe to every control item. Indeed, this had been used in a previous experiments (e.g. [Rosenfeld et al, 2004](#); [Mertens & Allen, 2008](#)).

Previous research has shown that reaction times slow with increased motor response complexity ([Henry & Rogers, 1960](#); [Anson, 1982](#); [Klapp, 2010](#)). By performing an additional task i.e. pressing a toe, for control items only, RT's should increase thereby reducing the RT-CIT effect.

## **Method**

### **Participants**

Guided by the literature described above, the average RT countermeasure effect (the difference in RT-CIT effect between control and countermeasure groups), when found, was large  $d = 1.03$ . Assuming a large countermeasure effect, a power analysis using G\*Power, with an effect size of  $d = 0.8$ , and  $\alpha = 0.05$  for a single group, suggested that 42 subjects per group would be sufficient for a power of 0.95. Ninety-eight participants (58 women and 4 undisclosed, aged between 18 - 42,  $Mean = 22.7$ ,  $SD = 5.1$ ), 44 per group, were recruited through a University online participant panel at the authors' institution and took part in the 30-minute testing session in return for £3 payment. Participants were assigned to each condition based on the experiment session they signed up to (four sessions with approximately twenty places were available). During sign up and during the experiment session participants were unaware of which group they were in.

### **Procedure**

The materials, RT-CIT, and procedure for the control group were identical to those of Experiment 1. For the countermeasure group, participants were told how the RT-CIT worked and instructed to "*perform a toe-tap or a toe wriggle when responding to unfamiliar images*" to try and fool the test. To ensure that participants

were indeed carrying out the instructed countermeasure, the experimenter visually observed participants during the experiment.

## Results

The data from two participants were removed from all analyses due to errors rates greater than 50% (58% and 89% from the control and countermeasure condition respectively) and one participant from the countermeasure group due to a technical error with the program. Of the remaining participants, trials (including target items) that exceeded the response deadline (2.3%), were faster than 200ms (0.73%) and incorrect (7.38%) were removed from the analysis (incorrect responses were used for the error analysis).

**Reaction Times.** Mean correct RTs were analyzed using a 2 (Item Type: crime item vs. control item)  $\times$  2 (Condition: control vs. countermeasure) mixed-ANOVA with Item Type as the within-subjects factor and Condition as the between-subjects factor. This revealed a significant main effect of Item Type,  $F(1, 93) = 112.2, p < .001, MSE = 34623, \eta_p^2 = .547$ , (RT-CIT effect was  $d = 1.1$  collapsed over condition) with RTs on crime item trials longer than those on control item trials (Figure 2.10) However, neither the main effect of Condition,  $F(1, 93) = .15, p = .696, MSE = 2178, \eta_p^2 = .004$ , nor the Condition  $\times$  Item Type interaction,  $F(1, 93) = .02, p = .882, MSE = 3.14, \eta_p^2 \approx .0$ , approached significance. A Bayes t-test was computed to evaluate the difference between the countermeasure and control condition using the crime item/control item RT difference. This revealed a  $BF_{01}$  value of 4.6 implying ‘substantial’ evidence for the null hypothesis suggesting that the countermeasure was ineffective.

**Error Analysis.** A 2 (Condition: Control vs. Countermeasure)  $\times$  2 (Item Type: Control item vs. Crime item) repeated-measures ANOVA on the mean error



rates revealed no main effect of Item Type,  $F(1, 93) = .061, p = .805, MSE = 1.52, \eta_p^2 = .001$ , or Condition,  $F(1, 93) = 1.35, p = .101, MSE = 430, \eta_p^2 = .029$ . Mean error rates for all trials were low ( $M = 5.76$ ) with no difference between the Control and Countermeasure groups. The Condition  $\times$  Item Type interaction was not significant,  $F(1, 93) = 1.35, p = .248, MSE = 33.4, \eta_p^2 = .014$ . A Bayesian t-test calculated using the crime item-control item differences for both Conditions revealed a  $BF_{01}$  of 2.6, implying ‘anecdotal evidence for the null hypothesis’.

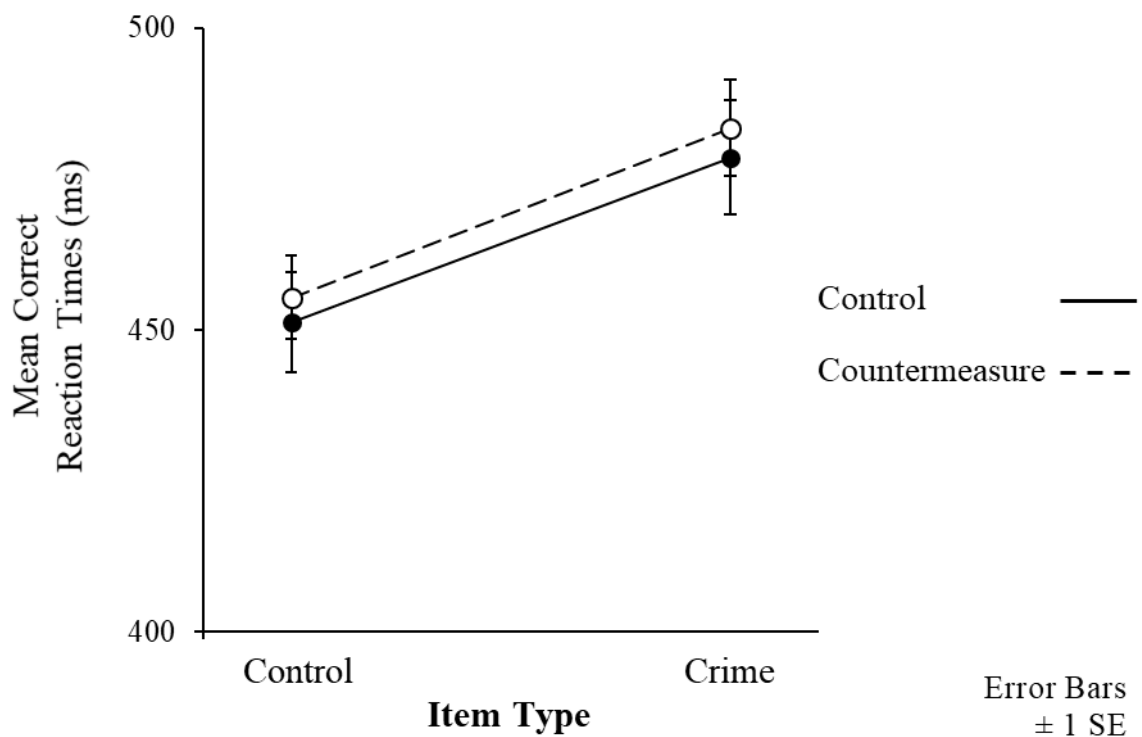


Figure 2.10. Experiment 3 - Mean correct RTs as a function of Item Type and Countermeasure Condition.

### Signal Detection Analysis

Using the same procedure as in Experiments 1 and 2, a signal detection analysis was conducted for both the countermeasure,  $AUC = .808$  and  $d = 1.14$ , and control group,  $AUC = .878$  and  $d = 1.52$ , using a simulated innocent group (Figure 2.11). Note that collapsed over condition,  $AUC = .843$  and  $d = 1.33$ .

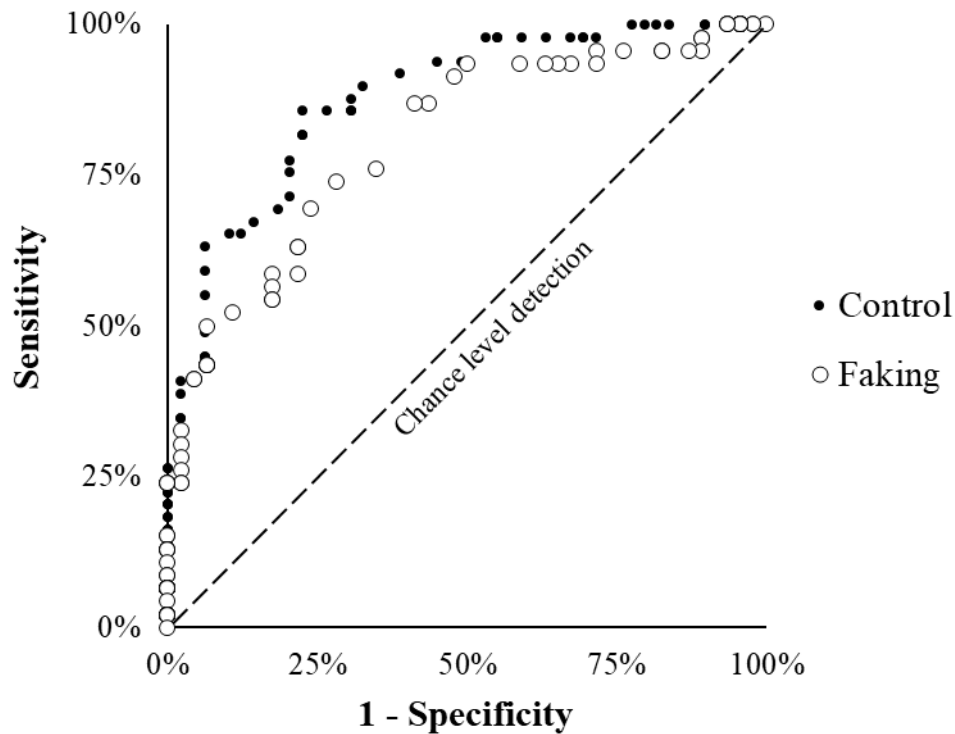


Figure 2.11. Experiment 3 - Signal detection curve (ROC) showing the detection sensitivity and specificity between guilty and simulated innocent participants

## Discussion

As in Experiments 1 and 2, scene stimuli produced a robust RT-CIT effect. However, of most interest, Experiment 3 tested the susceptibility of the scene-based RT-CIT to a physical countermeasure strategy; specifically, participants were asked to “perform a toe-tap or a toe wriggle when responding to unfamiliar images”. The logic behind this type of countermeasure is that performing an additional task on control stimulus trials might increase the RTs on those trials thus reducing the RT difference between crime and control stimuli; hence reducing the RT-CIT effect. There is currently little work specifically investigating the effects of countermeasures on the RT-CIT (Suchotzki et al., 2017). The findings in this experiment suggest that there was no difference between the control and countermeasure group in terms of

the crime-control RT difference - this lack of difference was supported by a Bayesian analysis.

The findings to mesh with those of Huntjens and colleagues (2012) who likewise found countermeasures to be ineffective (although arguably their study did not provide adequate countermeasure instruction). However, the current findings contrast with those from ERP (Mertens & Allen, 2008; Rosenfeld et al., 2004), and fMRI (Ganis et al., 2011) and aIAT (Verschuere, Prati & Houwer, 2009) studies in which countermeasures were influential. The differences may be explained by the fact that, as in the study by Huntjens and colleagues (2012), the current experiment used a standard RT-CIT procedure. In contrast, the methodologies for an ERP, aIAT, fMRI-based CIT are quite different in terms of the stimulus duration time, interstimulus interval and the use of additional physiological measurements which requires the participant having to remain stationary throughout the experiment.

### General Discussion

Determining whether a suspect recognizes crime-related information can be valuable and may be achieved using the RT-CIT. A substantial body of research has already established that the RT-CIT can be an effective means of revealing a suspect's knowledge when word stimuli are used. A smaller number of studies have also established that the RT-CIT works with images of discrete objects ([Visu-Petra et al., 2016](#); [Varga et al., 2015](#); [Suchotzki et al., 2015](#)). However, as well as objects, crime-related information can also take the form of scenes related to criminal activity. Linking a suspect with a crime scene will extend the range of situations in which the RT-CIT can be successfully applied. Importantly, knowledge of such scenes could not be easily tested by the presentation of a single word (or a limited number of words), nor by presenting images of single discrete objects. Although we know that the RT-CIT can determine whether a suspect recognizes one or more crime-related objects, the present study is the first to apply the test to the recognition of crime-related scenes.

At first glance, one might expect that scenes would work in an RT-CIT just as well as images of single objects. Indeed, this appears to be the case when using the physiological-base CIT ([Norman et al., 2020](#)). However, as detailed in the Introduction, due to differences in the way in which scenes and objects are encoded and processed we might expect the RT-CIT effect to differ between them. For example; scenes require encoding into memory over several glances ([Melcher, 2006](#)), scene recognition is possible without complete identification ([Cleary & Reyes, 2009](#)), scene information is processed rapidly requiring fewer attentional resources than objects ([Munneke et al., 2013](#)), and the PPA brain region responds only to scenes and not to objects ([Oliva & Torralba, 2006](#)). Clearly, there are reasons to question

whether the RT-CIT will be effective (or at least as effective) with scene-based stimuli than with object-based stimuli. Furthermore, scenes typically contain many objects and focusing on a single object, either during the ‘crime’ or at the test phase, might reduce the extent to which the RT-CIT can detect differences between the crime and control items if those objects are different. Similarly, limits in attentional capacity might reduce what is remembered from a scene at both encoding and retrieval phase. In addition, scenes may well contain more simple, global features (Oliva & Torralba, 2006) which might interfere with the processing of the deeper meaning of the scene. This could again have an effect at the encoding stage if participants simply encode and remember the gist of a scene.

Nonetheless, despite these concerns, a robust RT-CIT effect was obtained across a variety of scene-based stimuli in the three experiments. Specifically, responses to crime items were slower than to control items when either autobiographic or more recent memory was tested, and the difference between crime and control responses was equivalent to those obtained with object-based stimuli. Overall this study suggests that RT-CIT effect sizes ( $d = .784$  to  $1.48$ ) for scene stimuli were similar to those obtained in previous RT-CIT studies which used pictures of objects, ( $d = 1.05$  to  $1.24$ , Visu-Petra et al., 2016; Varga et al., 2015; Suchotzki et al., 2015) and words ( $d = 1.05$  [.93 - 1.17,  $CI^{95\%}$ ], Suchotzki et al., 2017). Consequently, this meant that RT-CIT diagnosticity ( $AUC = .746 - .919$ ) was also similar to those reported ( $AUC = .82$  [.77 - .87,  $CI^{95\%}$ ], Meijer et al., 2016).

These findings also suggest that the scene-based RT-CIT may be robust to at least one simple-to-implement countermeasure – a covert manual movement when responding to control stimuli. In the current study, it appears that making an additional physical movement did not interfere with the basic difference between RTs

to crime and control items. It is, of course, possible that participants simply did not apply the countermeasure, although this was monitored by an experimenter.

However, the finding of a trend for error rates to be higher in the countermeasure condition than in the control condition provides some, albeit relatively weak, evidence that participants were experiencing a higher cognitive load, consistent with them attempting to implement the countermeasure. The lack of an effect of the countermeasure is consistent with some initial findings ([Huntjens et al., 2012](#)) although inconsistent with others ([Mertens & Allen, 2008](#); [Ganis et al., 2011](#); [Rosenfeld et al., 2004](#); [Verschuere et al., 2009](#)). However, as noted earlier, there appears to be large methodological differences between the studies that have found countermeasures to be effective and those that have not. Determining which countermeasures are effective and under what conditions will be a useful goal for future research. In conclusion, the findings from this study suggest that the RT-CIT can be successfully applied to the recognition of scenes and produces an equivalent effect size to object-based tests.

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## CHAPTER 3

**Partners in crime:****Group testing increases the detection of concealed information for  
crime collaborators****Abstract**

High profile criminal activity is often planned and carried out by groups, with each member having individual roles and knowledge about the crime. The Concealed Information Test (CIT) can determine whether suspects recognize specific crime information and has been applied to groups to extract hidden information. However, interactions between group CIT testing, and whether crime information is shared among the group or not, requires investigation. In this study, pairs of participants encoded either shared or non-shared crime information, before undergoing a CIT either together or separately. The skin conductance CIT effect was larger when participants concealed shared information versus non-shared information, in the presence of their partners. No such effect, and potentially a reverse effect, was present for a participant tested separately. These initial findings suggest that the extent of crime knowledge within a group is important when applying group-based CITs for identifying specific group knowledge. \*Following the findings from part 1 of this study, in part 2 a group-based reaction time CIT was tested (Experiment 4) before comparing group and individual RT-CIT detection (Experiment 5). Finally, the effects of shared knowledge were tested in an RT-CIT (Experiment 6) using the stimuli from Experiment 2 - no benefit was found for group testing in the RT-CIT.



### Introduction

High profile criminal or terrorist activity is often carried out by groups of people and is typically more damaging compared to crimes committed alone (Zheng, Messner, Lu & Deng, 1997). For example, in 2015, four men planned and carried out a heist of the Hatton Garden Safe Deposit Company, UK, stealing around £200 million (Lashmar & Hobbs, 2018). Considering terrorism as another example, a small group of men was directly involved in the planning and execution of both the 2005 London bombings and the 2017 London Bridge attack. Crimes planned and committed by groups, typically constituting two to four members (Hodgson, 2007), account for around 10-17% of all offences (Vernham, Granhag & Mac Giolla, 2016) and this is on the rise (van Mastrigt & Farrington, 2011).

Despite this, deception research has focused largely on detecting lies in individual suspects (Vernham et al., 2016). This may be unsurprising given that most crimes are committed alone, and in practice, police are advised not to interview co-offenders together. Furthermore, interviewing groups of suspects introduces additional social and cognitive factors making deception detection theoretically and practically complex. Nevertheless, researchers have begun to conduct group deception research which has revealed new deceptive cues not normally found when interviewing suspects alone (Vernham et al., 2016). For example, lying pairs have been found to be more consistent between themselves compared to truthful pairs – a deception cue not found for individual liars (Granhag, Strömwall & Jonssonet, 2003). Furthermore, truthful pairs have been found to look more at each other during an interview compared to lying pairs who instead make more eye contact with the interviewer (Jundi et al., 2013). Clearly, initial work in group deception detection is promising.

The Concealed Information Test (CIT), is a memory detection test used to determine whether a suspect recognizes information about a crime that only the perpetrator(s) should know (Verschuere, Ben-Shakhar, & Meijer, 2011). Research demonstrates that, through measuring physiological responses (e.g. skin conductance) or using reaction times (RTs), the CIT can detect individuals that recognize specific crime information presented amongst irrelevant information, with excellent diagnosticity (Meijer, Selle, Elber, & Ben-Shakhar, 2014; Suchotzki, Verschuere, Van Bockstaele, Ben-Shakhar, & Crombez, 2017). Furthermore, the CIT effect, the difference in responses to crime and the control information, is large (Meijer et al., 2014). However, the CIT is nearly always administered to suspects individually, with only a handful of studies investigating the potential of conducting group-based CITs (Bradley & Barefoot, 2010; Breska, Ben-Shakhar, & Gronau, 2012; Breska, Zaidenberg, Gronau & Ben-Shakhar, 2014; Elaad, 2016; Meijer, Smulders, Harald & Merckelbach, 2010; and Meijer, Bente, Ben-Shakhar & Schumacher, 2013).

Group CITs have been proposed as a method for reliably extracting information, not yet known by the investigating authorities, from groups of known perpetrators - an approach coined the “Searching CIT” which can also be used with individual suspects (Nakayama, 2002; MacLaren, 2001; Osugi, 2011). As an example, in one study, twelve participants were given the date, location and target of an upcoming mock terrorist act before undergoing a CIT together. In that study, the correct information was successfully extracted from the group as a whole, for all questions asked, allowing the investigator to identify the details of the planned crime (Meijer et al., 2010). In a follow up study, twenty groups of five participants planned a mock terrorist attack based on a list of potential countries, cities and streets (Meijer

[et al., 2013](#)). With simultaneous data recording, dynamic questioning and direct online analysis in each group, the exact street of the planned act was detected in 35% of groups with a 10% false positive rate (the country was detected in 19 of the 20 groups with no false positives, the city was detected in 13 of these 19 groups with two false positives, and the street was detected in 7 of these 13 groups with two false positives) ([Meijer et al., 2013](#)). Other studies using group CITs have seen information extracted concerning: events that group members only passively witness whilst they are engaging in another task ([Bradley & Barefoot, 2010](#)), and planned mock crimes involving kidnapping and robbery ([Breska et al., 2014](#)). Group CIT studies have also investigated the possibility of extracting information from groups where individual members have only partial knowledge about the crime ([Elaad, 2016](#)) with another study testing automated algorithms for doing so ([Breska, Ben-Shakhar, & Gronau, 2012](#)). These group CIT studies all measured skin conductance responses as well as occasionally measuring parasympathetic measures like heart rate. One study has also conducted a group CIT using P300 event potentials ([Meixner & Rosenfeld, 2011](#)). Note that, to our knowledge, no studies have tested reaction time measures in group CIT testing.

Group based CIT studies so far have been concerned with the practical efficiency with which information, shared by all or some of a group, is extracted. However, it is not yet known whether the magnitude of the CIT effect differs when information is either shared by the group or known exclusively only by one or more individual members. Furthermore, no study has systematically compared the CIT effect for individuals tested together simultaneously versus alone. This is important to explore as there is evidence to suggest that there may be an interaction between

whether information is shared, or not, and whether crime partners undertake a CIT together or separately.

As a memory detection test, the CIT has been shown to be susceptible to changes in explicit memory ([Gamer, Kosiol & Vossel, 2010](#)). It is well known that encoding and retrieving memories in a group differs from that for an individual. Groups asked to recall information encoded together (known as collaborative encoding), perform worse than groups who encoded that same information individually ([Marion & Thorley, 2016](#)). This is termed collaborative inhibition and is a robust finding occurring in the recall of words ([Pereira-Pasarin & Rajaram, 2011](#)), sentences ([Kelley, Reysen, Ahlstrand, & Pentz, 2012](#)) and storylines ([Takahashi & Saito, 2004](#)). Various mechanisms have been proposed to underlie the collaborative inhibition effect (see [Barber, Harris, & Rajaram, 2015](#)). One example, based on the Transactive Memory System proposes that collaborative inhibition may be partially due to the dividing of responsibility between group members during the encoding of group information ([Hollingshead & Brandon, 2003](#)). A popular explanation is provided by the retrieval strategy disruption hypothesis which theorizes that individual group members' memory strategies are disrupted when collaboratively retrieving information ([Basden, Basden, Bryner, & Thomas, 1997](#)). Although collaborative inhibition occurs robustly in recall tasks, it is rarely observed for recognition tasks ([Blumen & Rajaram, 2009](#)). It is proposed that this is because the recognition cues provided by the stimulus equally disrupt the participants' retrieval processes, regardless of whether they are remembering collaboratively or individually, thereby negating the collaborative inhibition effect ([Rajaram & Pereira-Pasarin, 2010](#)).

Collaborative inhibition is a potential problem for group-based CIT testing. With this in mind, a collaborative inhibition paradigm was incorporated into a P300 CIT experiment where participants either carried out a mock crime alone or collaboratively in pairs before undergoing separate CITs (Lu et al., 2018). The results revealed that for P300 amplitude, the CIT effect was smaller ( $n = 36$ ,  $p = .047$ ) for the collaborative crime pair (note no differences were found for P300 RTs or latency). In their abstract, the authors implied that their findings were evidence for collaborative inhibition and consequently concluded that the “*P300-based CIT is not applicable when used to identify collaborative crime perpetrators*” (Lu et al., 2018). Their experiment appears to be the first CIT study where the effects of collaborative encoding within a mock crime were tested.

One limitation with the traditional collaborative inhibition paradigm is that participants encode information individually before then either retrieving it collaboratively or individually (Marion & Thorley, 2016). Considering this, an alternative and simpler explanation posits that collaborative inhibition is simply an artefact caused by a mismatch in Encoding Specificity (Tulving & Thomson, 1973). According to Encoding Specificity theory, groups encoding and retrieving the information alone benefit from both context-dependent learning (i.e. the lack of participants in their physical surroundings) as well as transfer-appropriate processing, (i.e. similar cognitive processes used during encoding and retrieval) (Barber, Rajaram & Aron, 2010). However, for group members that encode information individually but then retrieve it collaboratively, there is a mismatch in encoding specificity which consequently produces the effect termed collaborative inhibition. In line with this theory, collaborative retrieval of information should be superior when that information is encoded collaboratively. If true, then there would be a potential

benefit of testing co-offenders together in a CIT. However, no study has yet found a collaborative retrieval advantage following collaborative encoding, although some have seen an elimination of collaborative inhibition ([Marion & Thorley, 2016](#)).

In addition to the memory-based effects that occur in group testing, other processes have been shown to be important in group testing. Task co-representation is an established effect that occurs when participants undertake a task together ([Elekes, Bródy, Halász & Király, 2016](#)) and, broadly, is the process of forming representations of what your partner is focusing on, which consequently affects your own performance or behavior in a task ([Böckler, Knoblich & Sebanz, 2012](#)). In one study, participant pairs sat next to each other and performed a two-choice task while EEGs were recorded ([Böckler & Sebanz, 2012](#)). One observation was that P300 amplitudes were significantly reduced when the partner held a different focus of attention, demonstrating that the focus of one's attention can be influenced by the presence of others. Presumably in a group CIT, this implies that when a participant knows that their partner is attending to the same shared crime information as them, their attentional focus is affected, causing either an increased or decreased orienting response. Neurological studies of Theory of Mind processes have shown that certain brain regions are more active when we think about what others are thinking and this could therefore also impact physiological orienting ([Koster-Hale & Saxe, 2013](#)). Finally, group testing introduces other social factors which are likely to influence the CIT when it is conducted in a group setting. Numerous studies have shown that the mere presence of others can influence behavior and task performance ([Zajonc, 1965](#)) as well as physiological arousal ([Chapman, 1973](#); [Hrycaiko & Hrycaiko, 1980](#); [Mullen, Bryant, & Driskell, 1997](#)), particularly skin conductance responses ([Mullen, Bryant, & Driskell, 1997](#)).

As described, various additional social and cognitive processes are likely to occur in group CIT testing. To illustrate the potential effects of these, consider this scenario. Two thieves plan and execute a heist of a valuable item before later undergoing a CIT. The CIT examiner is aware that some information about the crime is likely known by both of the suspects, such as the valuable stolen item (this would be *Shared Knowledge*), whilst other information is likely known only to one of the suspects, such as a tool used in absence of the suspects' partner (this is termed *Exclusive Knowledge* in this study). Consequently, the suspect who did not see their partner use a tool during the crime would not know about that specific information, i.e. that crime detail to them would be unknown (termed *Unknown Knowledge* throughout this study). Should the examiner administer the CIT to each suspect separately or together? If suspects are tested separately then encoding specificity would predict that the CIT effect would be larger when suspects view crime items encoded exclusively in absence of their partner. The other way around, the CIT effect may be larger when suspects view shared information together due to Encoding Specificity, Task Co-representation and/or Theory of Mind.

The current study tested whether the CIT effect (skin conductance and heart rate responses) differs between suspect pairs, who share or don't share crime knowledge, undergo the CIT together or separately. To achieve this, two mock crime videos were filmed, and subsequently viewed, from a 1<sup>st</sup> person perspective, of two thieves carrying out a heist together. During this heist, the thieves encounter crime information together (*Shared Knowledge*) and individually (*Exclusive Knowledge* aka non-shared) with information encoded individually not known by the other partner (thereby *Unknown Knowledge*). Given the linear narrative of the mock crime videos, Experiment 1 was first conducted to check that the crime details in each

knowledge category did not differ in general salience. In Experiment 2, participant pairs watched the mock crime videos before undergoing a CIT either *Together* or *Separately*. Experiment 3 provided a replication Experiment 2 before data from both experiments were merged for a combined analysis.

In the second part of this study,<sup>1</sup> it was tested whether the RT-CIT effect occurs during paired testing of suspects concealing recognition of autobiographic scenes (Experiment 4), before testing whether this group RT-CIT effect differs when participants are tested separately (Experiment 5). Finally, the interaction between knowledge (Shared, Exclusive or Unknown) and paired testing in the RT-CIT is explored by replicating Experiments 2 but using an RT-CIT paradigm (Experiment 6). All studies were approved by the departmental ethics committee at the authors' institution.

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<sup>1</sup> This paragraph was removed along with; The second abstract paragraph, Table 1, Figure 3 and Part 2 of this chapter prior to submission of this study for publication i.e. the paper focused only on the physiological CIT



## PART 1: PHYSIOLOGY MEASURES

### Experiment 1 - Stimulus Check

Due to the pre-recorded and linear narrative in the mock crime video, the crime details did not lend themselves to being counterbalanced between knowledge types (*Shared*, *Exclusive* and *Unknown*) i.e. the shared knowledge crime items could never be presented as exclusive knowledge items. Therefore, Experiment 1 was conducted to verify that physiological CIT effects for each three knowledge types (each containing three crime items), did not differ from each other.

#### Method

##### Participants

A sample size of thirty-two participants per group was planned for the main experiment (see Experiment 2). Accordingly, for this stimulus check experiment, thirty-two self-selected adults (24 women), aged between 18 - 47 years (*Mean* = 23, *SD* = 7.0, one undisclosed) were recruited through a university online participant panel at the authors' institution. Each received £8 payment for partaking in the 60-minute testing session and the opportunity to receive their 'lie detection score'. Participants were incentivized with the chance to win a £25 Amazon voucher if they obtained the lowest 'lie detection score'.

##### Design

Individual participants watched a mock crime video containing nine crime details before undergoing a physiological CIT alone. In Experiment 2, these crime details were categorized as three different Stimulus Sets (translating into the different Knowledge Types – see [Figure 3.1](#)). To confirm the equivalence of these Stimulus Sets, a within-subject design with factor Stimulus Set (Suspect A, Suspect B vs.

Shared) and dependent variables of SCR and Heart Rate change ( $\Delta$ HR) CIT effects (normalized crime item responses) was used.

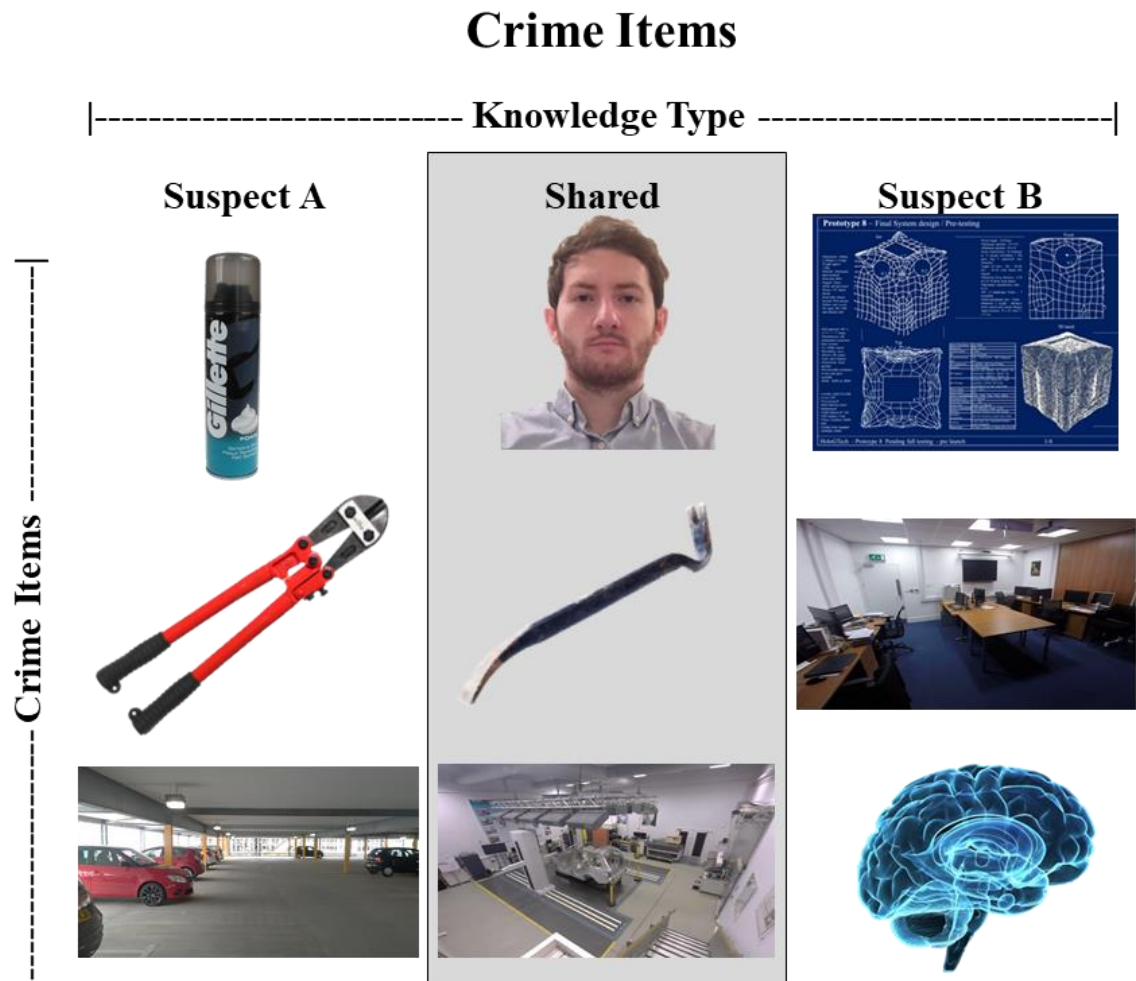


Figure 3.1. Nine crime items separated by knowledge type (or Stimulus Set for Experiment 1), from the mock crime videos used in this study

### Procedure

Participants were provided with an overview of the study, including their right to withdraw, given the opportunity to ask any questions, and invited to provide consent and demographic information (age and gender).

**Mock Crime Video.** Participants were told that they would watch a 12-minute, 1<sup>st</sup> person perspective video (viewed in 3D active stereo) filmed from the viewpoint of a thief carrying out a heist of a valuable item. Participants were told to

imagine as best as they could that they were the thief in the video (Figure 3.2).

Participants stood alone in a cubicle whilst watching the video with headphones on.

The mock crime video started with an onscreen planning phase where the thief (referred to as 'suspect' from here), whilst viewing the heist plans, was phoned by a superior, *Mike*, whose picture was displayed on a phone on screen (italics indicate crime items). The suspect was told about the theft they would conduct involved breaking into a secret lab, stealing a prototype hologram device and related files before passing it onto *Mike*. The suspect then added their tools to their bag before leaving for the target lab. Starting just outside the secret *lab*, the suspect forced open the lab door using a *crowbar* before disabling an alarm system. After this, the suspect used some *shaving foam* to cover up a CCTV camera before breaking a padlock with some *bolt cutters* to access the prototype device which they then stowed in their bag. The suspect then accessed an adjacent room which had a copy of the device *blueprints* on the wall which they photographed. Moving into a connected *office* the suspect then accessed a password protected computer by correctly interacting with an image password of a *brain hologram*, stealing some files related to the device and leaving the facility. After this, the suspect met with Mike alone in a multi-story *carpark* to hand over the stolen items. Throughout, a series of video 'thought bubbles', current objectives and an inventory of the items used in the crime appeared at appropriate points during the video.

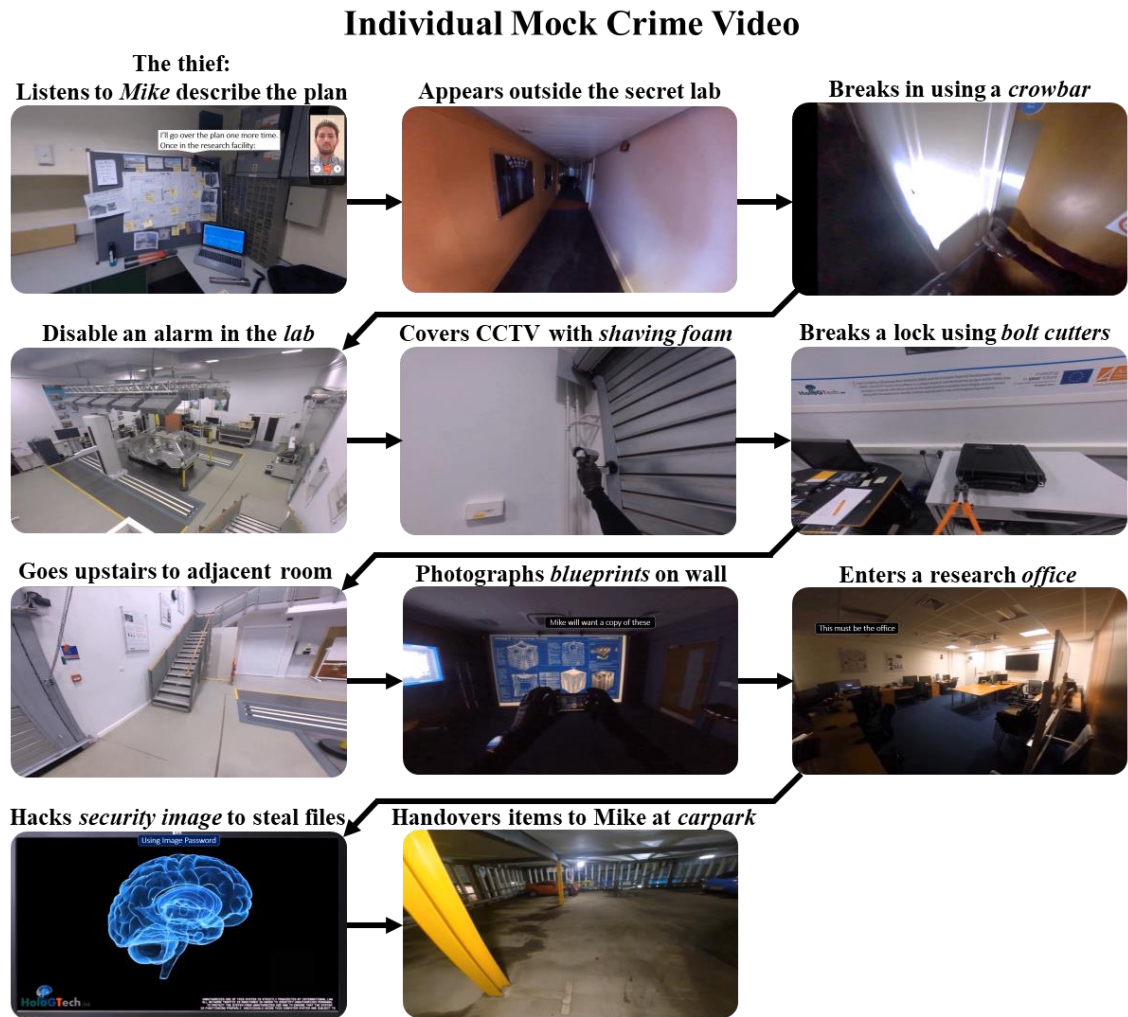


Figure 3.2. Key scenes from the individual mock crime video with crime items *italicized*

**Instructions.** Following the mock crime video, participants were asked to imagine that they had been contacted by the authorities, informing them that they were now a suspect in a recent crime and would therefore undertake a lie detection test. They were reminded to try to appear as innocent as possible and therefore to deny any knowledge of the crime.

**The CIT.** Participants were taken to a different cubicle to undergo the CIT. The EDA and ECG electrodes were then applied (see below), and participants were reminded that they were being filmed during the CIT and that they should try to remain as still as possible. Previewing all items in the CIT prior to testing is

recommended to reduce the novelty for each stimulus, thereby removing this potential orienting response confound (Verschuere & Crombez, 2008). It also allowed the experimenter to visually explain the CIT procedure as well as familiarize participants with the task. During the preview, participants were given a sheet with each CIT question and accompanying (unlabeled) stimuli including all control and crime items. Participants were not reminded, or informed which items related to the crime. Following the preview, participants were invited to ask any questions before the CIT started.

The CIT consisted of nine blocks each containing one crime item and four control items all presented as images on a computer monitor (Table 3.1). CIT blocks were presented in a random order and each began with a question presented for ten seconds followed by a 1s blank (grey screen). The five items were then presented sequentially for five seconds followed by a 10s blank screen (Figure 3.3). The first item presented in each CIT question was a buffer; a control item used to absorb the initial orienting to that item group. Participants were instructed to think the word ‘no’ or ‘don’t know’ in response to each item but remain silent through (this was done to ensure participants did not disrupt each other’s physiological responses when taking the test as a pair planned for Experiment 2). All images were resampled to 1920 x 1080 pixels and presented full-screen on a 24” LCD monitor, 16:9 aspect ratio at a resolution of 1920 x 1080 pixels. Participants sat approximately 50cm from the screen with the center of the screen at approximately eye level. During the CIT the experimenter left the room to observe the participants through a live camera feed; the participants then started the CIT.

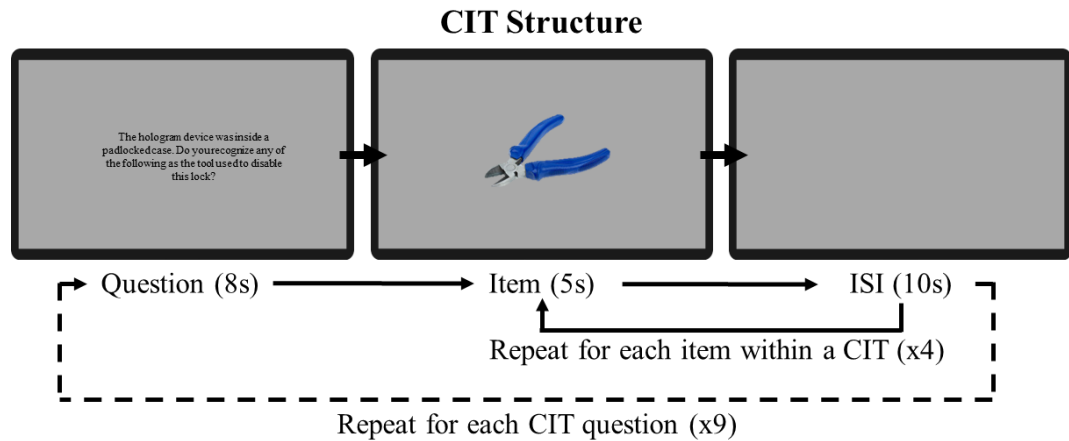


Figure 3.3. Example of one physiological CIT structure for one CIT item

**Post CIT Questionnaire.** After completing the CIT, participants were given a paper-based questionnaire consisting of multiple-choice questions to check that they had remembered the crime items. Participants were also asked to rate their motivation to beat the CIT on a 6-point scale (1 = *no motivation*, 6 = *highly motivated*), their stress during the CIT on a 6-point scale (1 = *no stress* to 6 = *highly stressed*), how immersive they found the mock crime scenario and how well they felt they appeared innocent on a 6-point scale (1 = *not immersive* 6 = *highly immersive*). Participants were also asked to provide an open answer to the question: “*Did you do anything to try and fool the polygraph test? If you did or didn’t please bullet point below – either case is fine.*” Finally, participants were debriefed.

Table 3.1. All nine CIT questions, with corresponding crime and control items

(provided as text here), for each Knowledge type used in this study.

|           | Questions   | Crime Item   | Control Items     |                    |                  |                |
|-----------|---|--------------|-------------------|--------------------|------------------|----------------|
| Suspect A | The CCTV camera in the lab was masked. Do you recognize any of the following as the method used to cover the CCTV camera?                                 | Shaving Foam | Blu Tack          | Duct Tape          | Spray Paint      | Cloth          |
|           | The hologram device was inside a padlocked case. Do you recognize any of the following as the tool used to disable this lock?                             | Bolt Cutters | Hack Saw          | Wire Cutters       | Lock Picks       | Metal Snips    |
|           | The stolen items were handed over at a predetermined location. Do you recognize any of the following as the location as where the handover took place?    | Car Park     | Overpass          | Park               | Rail Station     | Town Centre    |
| Suspect B | The door to the lab was forced open. Do you recognize any of the following as the device used to force the door?  | Crowbar      | Sledge hammer     | Hydraulic Ram      | Lock Drill       | Door Ram       |
|           | We have the accomplice who organised the theft and received the device in custody. Do you recognize any of the following as the accomplice in this crime? | Mike         | Chris             | James              | Tom              | Steve          |
|           | Few have access to the highly secret lab that was broken into. Do you recognize any of the following as the lab that was broken into?                     | Lab E        | Lab A             | Lab B              | Lab C            | Lab D          |
| Shared    | The hacked computer required a secondary image password. Do you recognize any of the following as the image password?                                     | Brain        | Heart             | Clock              | Earth            | Jellyfish      |
|           | The review room next to the office displayed information about the device. Do you recognize any of the following as the information on the screen?        | Blueprints   | Financial Details | Facility Locations | Bespoke Software | Future Patents |
|           | The office on the first floor was accessed using a keycard. Do you recognize any of the following as the specific office accessed?                        | Office C     | Office A          | Office B           | Office D         | Office E       |

### Physiological Data

Physiological data were recorded and processed in the same manner as reported by Norman and colleagues, 2020. Electrodermal activity (EDA) and heart rate were recorded using an MP36R data acquisition unit (*Biopac Systems Inc*) with pre-gelled disposable Ag/AgCL electrodes (EL507 and EL501 for EDA and heart rate respectively). EDA electrodes were attached to the distal phalanges of the first and middle finger of the non-dominant hand with EDA signals sampled at 1000Hz at 2000 gain and filtered using a 66.5Hz low pass filter. For heart rate, Electrocardiogram (ECG) electrodes were placed in a standard Einthoven Lead I Configuration: one placed on the ventral side of the dominant wrist, another on the non-dominant lateral aspect of the distal fibula, and the third electrode utilising the EDA ground electrode placed on a non-dominant distal phalange. ECG signals were sampled at 1000Hz at 1000 gain, with a 66.5Hz low pass filter and a 0.5Hz high pass filter. Electrodes were attached for approximately 5 minutes before data collection. A webcam was used to record participants from the front view to allow noise removal if participants made substantial movements.

Skin conductance responses were defined as the difference in absolute magnitude of tonic skin conductance peaks and their respective peak onsets. Skin conductance peaks were identified using an *AcqKnowledge* v4.2 propriety algorithm (Kim, Bang & Kim, 2004) with parameters ensuring peak onsets were within a 0.5-5s window following stimulus presentation and maximum peaks within 10s (Gamer, 2011). The output was manually checked for errors. For heart rate, an *AcqKnowledge* propriety Heart Rate algorithm was used on the ECG signal to detect R peaks, classify the time interval between them, and automatically filter artefacts. The R-R interval was then converted to instantaneous heart rate (beats per minute) before



baseline-correction via subtraction of the 1s mean heart rate prior to stimulus onset.

The average baseline-corrected heart rate was calculated between stimulus onset and 15s after stimulus onset, resulting in mean heart rate change. This has previously been shown to outperform other measures of heart rate change when analysing physiological data from the CIT ([Gamer, 2011](#)). Due to individual differences in physiological responsiveness, within-subjects standardised scores (z-scores) were calculated for each individual measure ([Ben-Shakhar, 1985](#)).

Data from a trial were removed if there was excessive movement (e.g. posture shifts, large head movements, face touching etc. seen on the video) within a 0-2s window prior to individual stimulus onsets ([klein Selle, Verschuere, Kindt, Meijer & Ben-Shakhar, 2016](#)). Whole signals were removed if the sensors became dislocated or dislodged during the experiment. Participants with a standard deviation of raw SCR responses below  $0.01\mu\text{S}$  were considered EDA non-responders and the EDA data were removed from analysis ([klein Selle et al., 2016](#)). Finally, the first trial in each CIT block, always a control item, was removed prior to analysis as its sole role was to absorb the initial orienting to that CIT item group.

**Exclusions.** From all trials, eight (0.6%) were removed from the analysis due to large movement artifacts; five large head movements, two posture shifts and one large hand movement. In total three (9%) participants were considered EDA non-responders and their data were excluded from the SCR analysis. Finally, due to a technical error data was not recorded for the last CIT for four participants.

## Results and Discussion

### Skin Conductance and Heart Rate

The key finding was that neither the SCR nor  $\Delta$ HR CIT effects differed between Stimulus Sets for participants tested individually. Mean normalized SCR CIT effects were analyzed using a repeated-measures ANOVA with factor Stimuli Set (Suspect A vs. Suspect B vs. Shared) (Figure 3.4). This revealed no significant difference between Stimulus Sets,  $F(2, 56) = .596, p = .555, MSE = .208, \eta_p^2 = .021$ . Mean normalized  $\Delta$ HR CIT effects (a heart rate decrease) were analyzed in the same manner as SCR. This also revealed no significant difference between Stimulus sets,  $F(2, 62) = .091, p = .913, MSE = .026, \eta_p^2 = .003$ . Collapsed over stimulus set, the CIT effect was large for SCR ( $d = .873$ ) and  $\Delta$ HR ( $d = .984$ ).

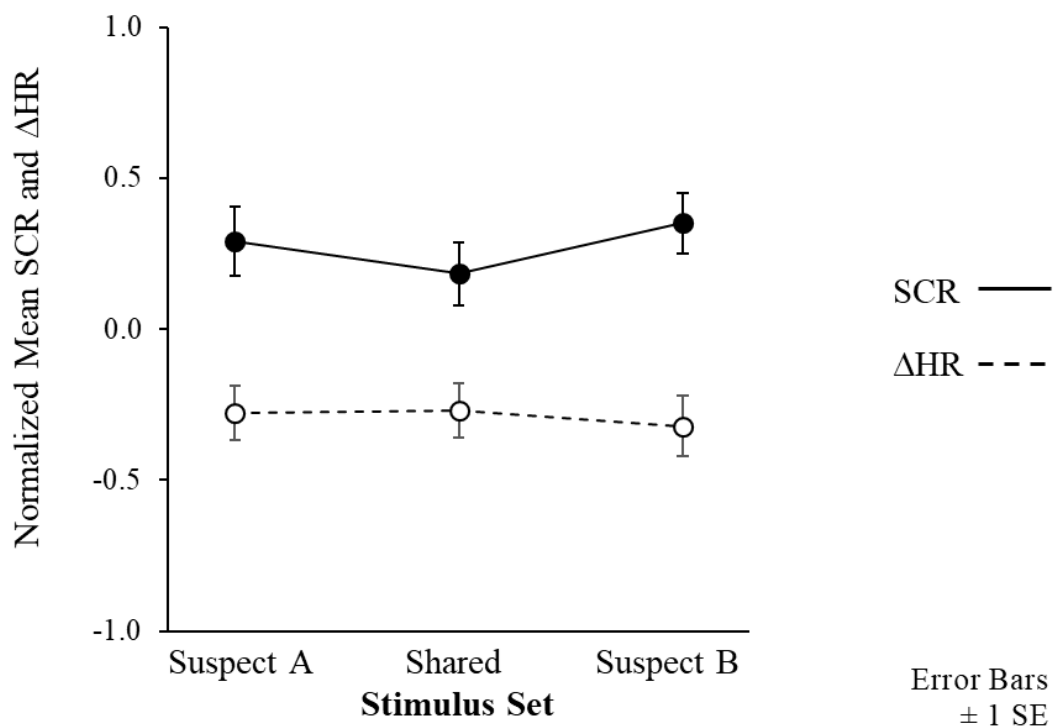


Figure 3.4. Experiment 1- Mean normalized SCR and  $\Delta$ HR CIT effect as a function of Stimulus Sets.

### **Bayesian Analysis**

Where frequentist analysis reveals a non-significant difference, the Bayes factor  $BF_{01}$  is sometimes reported to quantify the degree to which the data support the null hypothesis ([Wagenmakers et al., 2018](#)). Therefore, to further assess the non-significant differences reported above for Stimulus Sets, a Bayesian repeated-measures ANOVA was performed on the SCR and  $\Delta$ HR CIT effect using JASP software ([JASP Team, 2018](#)). For SCR and  $\Delta$ HR CIT variables this revealed a  $BF_{01}$  of 5.64 and 9.84 (respectively), implying ‘substantial evidence for the null hypothesis’ ([Jefferys, 1961](#)) providing evidence that the stimulus sets did not differ.

### **Post CIT Questionnaire**

Participants correctly recalled 97.5% of crime items, with seven participants forgetting one of the nine crime items and one forgetting two. Overall participant self-reported motivation was moderate with Mean = 5.2,  $SD = 0.6$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>); self-reported stress during the CIT was average with Mean = 3.7,  $SD = 1.3$  (range = 1<sub>no stress</sub> to 6<sub>highly stressed</sub>); and self-reported immersion of the mock crime video was average with Mean = 4.4,  $SD = 1.1$  (range = 1<sub>not immersive</sub> to 6<sub>highly immersive</sub>). Twelve participants (38%), reported using some form of countermeasure to fool the test: four remained calm; three gave special attention to the control items; two tried to control their heart rate; one thought about something else; one tried to control their breathing and one actively tried to suppress memory of the crime items.

### **Discussion**

This experiment was conducted to ascertain whether the different sets of stimuli (relating to Shared, Exclusive or Unknown Knowledge) from the mock crime video elicited equivalent CIT effects when participants were tested individually. This stimulus check was required as no counterbalancing of CIT items could be achieved

given the pre-recorded nature of the mock crime videos. The results clearly indicated that the stimulus sets did not differ for either the SCR or  $\Delta$ HR CIT variables and therefore were appropriate for use in Experiment 2. Finally, collapsed over stimulus sets, the CIT effect was large for SCR and  $\Delta$ HR.

### Experiment 2: Shared Knowledge and Paired Testing

Experiment 2 examined whether the CIT effect (SCR and  $\Delta HR$ ) differed when pairs of suspects either took a CIT together or separately, or were exposed to different information in the crime. Participants each watched a mock crime video and encoded both *Shared* crime knowledge (information both participants saw) and *Exclusive* knowledge (information that their partner did not see). As partner A would not be aware of the exclusively known items encoded by partner B, partner A's exclusive knowledge simultaneously acted as *Unknown* knowledge for partner B and vice versa (see [Figure 3.1](#)). Therefore, each partner had three types of crime knowledge, *Shared*, *Exclusive* and *Unknown*. Following the mock crime, participant pairs then underwent a physiological CIT either in the same room at the same time (i.e. *Together*) or one at a time sequentially (tested *Separately*). Consequently, the experimental study had a 2 (Tested: Together vs. Separate) x 3 (Knowledge Type: Unknown vs. Exclusive vs. Shared) mixed-design with Knowledge as the within-subjects factor and normalized SCR and  $\Delta HR$  CIT effects as dependent variables.

#### Method

##### Participants

Previous literature was examined to guide sample size however only one CIT study has considered the impact of testing participants following a collaborative mock crime. In that study the P300 amplitude CIT effect was found to be significantly smaller for items encoded collaboratively in a mock crime and the effect size was large ( $n = 36$ ,  $p = .047$ ,  $\eta_p^2 = .12$ ) ([Lu et al., 2018](#)). Based on these findings, a power analysis using G\*Power ([Faul, Erdfelder, Lang, & Buchner, 2007](#)), with an effect size of  $\eta_p^2 = .12$ , and  $\alpha = 0.05$  for a single group, suggested a minimum sample size of 21 subjects would be sufficient for a power of 0.95. Because up to 25% of

participants could be SCR non-responders (Venables and Mitchell, 1996) the sample was increased to 32 per each of the two groups for a total sample size of 64.

Sixty-four self-selected participants (30 women and 2 non-disclosing), aged between 18 to 29 years ( $Mean = 21$ ,  $SD = 2.8$ ) were recruited in pairs through a university online participant panel at the authors' institution. All participant pairs had an existing relationship with one another as would be expected for criminal partners. Participants received £6 payment for partaking in the 50-minute testing session and the opportunity to receive their 'lie detection score' along with a £25 Amazon voucher each if, as a pair, they obtained the lowest score. Participants were allocated in an alternating fashion between either the paired or the separate condition.

### **Procedure**

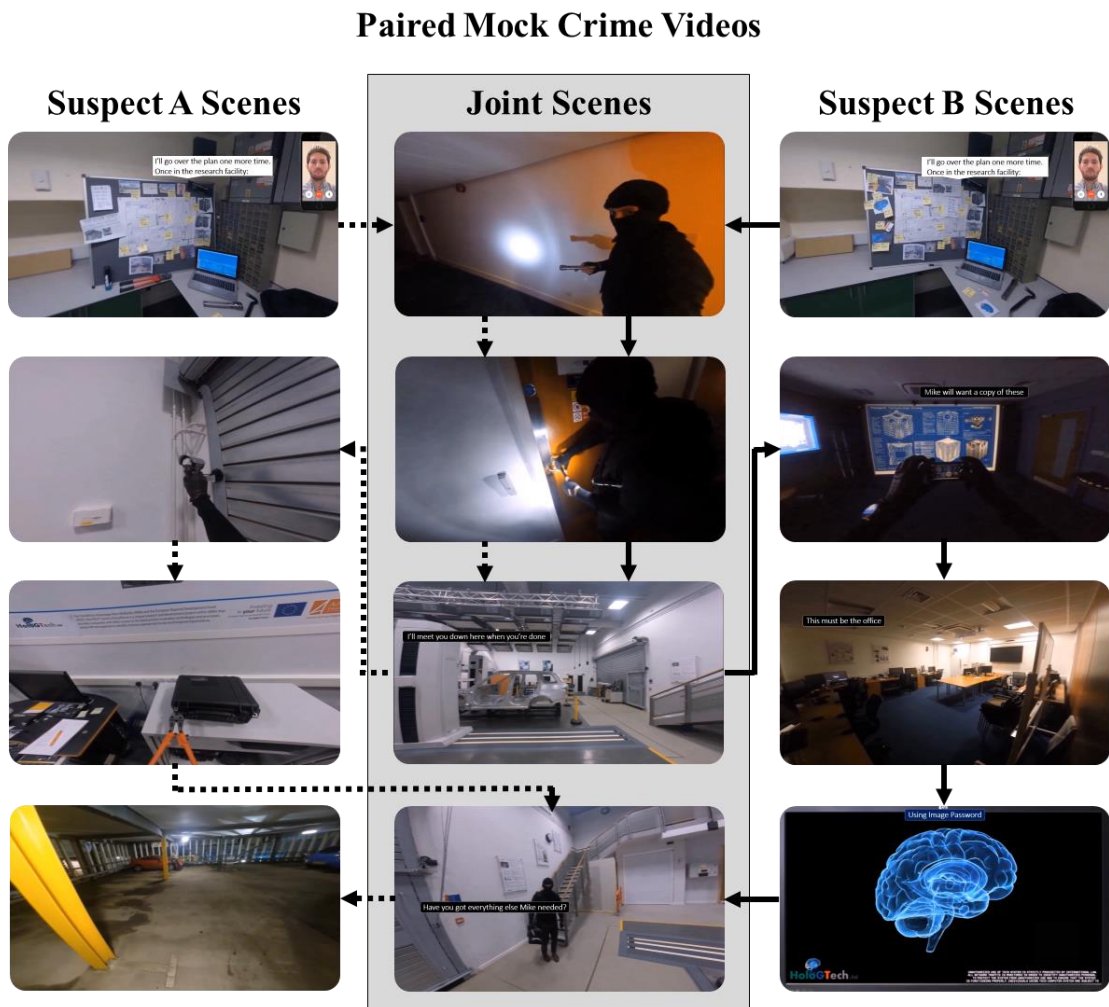
Participants were provided with an overview of the study, including their right to withdraw, given the opportunity to ask any questions, and invited to provide consent and demographic information (age and gender).

**Mock Crime Video.** Similar to Experiment 1, participants were told that they would both watch two separate 8-minute, 1<sup>st</sup> person perspective videos (played on two 3D active stereo monitors) filmed from the viewpoint of two thieves carrying out a heist of a valuable item together (Figure 3.6). Participants were told to imagine as best as possible that they were a thief in the video they were watching. They were also told that they would see their thief partner in the video and that they should try to imagine that the partner in the video was actually their participant partner in reality. It was explained to both participants that their 'real-life' partner would be seeing the viewpoint of the crime partner in the video. The videos were watched by both suspects at the same time on two separate screens with the suspects standing back to back with headphones on so neither could hear or see the other's video.

Participants were instructed not to communicate what they saw to their partner at any point during the study – based on experimenter observation, this did not happen. It was ensured that both participants knew that when their crime partner was in the video scene, both participants would see the same crime details.

The same as Experiment 1, both mock crime videos started with an onscreen planning phase where the thieves, whilst viewing the heist plans, were phoned by a superior, *Mike*, whose picture was displayed on a phone on screen (italics indicate crime items). The suspects were told about the theft they would conduct with their partner which involved breaking into a secret lab, stealing a prototype hologram device and related files before passing it onto *Mike*. The suspect then added their respective tools to their bag before leaving to join their partner outside the target lab. Starting just outside the secret *lab*, both suspects forced open the lab door using a *crowbar* before disabling an alarm system. After this, the suspects separated into different areas within the facility where they could not see what the other was doing and hence would be obtaining exclusive information. The crime details seen in this phase would then become the Exclusive knowledge (not known to their partner). Suspect A used some *shaving foam* to cover up a CCTV camera before breaking a padlock with some *bolt cutters* to access the prototype device which they then stowed in their bag. During this time, Suspect B accessed an adjacent room which had a copy of the device *blueprints* on the wall which they photographed. Moving into a connected *office* the suspect then accessed a password protected computer by correctly interacting with an image password of a *brain hologram* before then stealing some files related to the device before they then met with Suspect A to leave. After this, Suspect A met with Mike alone in a multi-story *carpark* to hand over the stolen items. Throughout, a series of video ‘thought bubbles’, current objectives and

an inventory of the items used in the crime appeared at appropriate points during the video.



*Figure 3.5. Selected scenes from the paired mock crime video used in Experiments 2 and 3, with shared and exclusive scenes for each suspect highlighted*

**Testing Condition.** If the participants were being tested separately, one participant was instructed to wait in a room next door whilst the other took the CIT. Whilst waiting for approximately 15 minutes, participants were free to do as they wished. If participants were tested together, then both participants underwent the same CIT, sat next to each other, in the same room simultaneously. Participants were reminded to remain silent, not communicate and that they were being filmed



throughout. The remaining procedure (Instructions, The CIT, Post CIT Questionnaire and the Physiological Data processing) was identical to that in Experiment 1.

### **Exclusions**

Out of all possible trials, twenty-two (0.77%) were removed due to large movement artifacts, ten posture shifts, eight large head movements, three face touch and one large sigh. In total three (4.7%) participants were considered SCR non-responders and their data were excluded from the SCR analysis all in the Together condition). Five (7.8%) participants' heart rate data were excluded from the analysis due to poor signal quality from dislodged sensors.<sup>2</sup> Finally, due to a technical error data was not recorded for the last CIT for two participants and for the first trial for one participant.

## **Results**

### **Skin Conductance Responses**

The key finding was that participants' SCR CIT effect was larger for items that participants both encoded (i.e. the Shared knowledge) compared to items that participants encoded exclusively, but this was only the case when participants were tested Together.

Mean normalized SCR CIT effects were analyzed using a 2 (Tested: Together vs. Separate) x 3 (Knowledge: Unknown vs. Exclusive vs. Shared) mixed-ANOVA with Knowledge as the within-subjects factor (Figure 3.6). This revealed a significant

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<sup>2</sup> Some ECG sensors did not remain adequately secured to the participant during this experiment. This was assumed to be due to the participants sweat caused by high summer temperatures which prevent optimal sensor adhesion. Additional tape was used to reduce this issue.

main effect of Knowledge,  $F(2, 120) = 14.9, p < .001, MSE = 6.18, \eta_p^2 = .199$ , and Testing,  $F(1, 60) = 4.1, p = .047, MSE = 1.16, \eta_p^2 = .064$ . There was also a significant two-way interaction between: Knowledge and Testing,  $F(2, 120) = 5.25, p = .007, MSE = 2.18, \eta_p^2 = .080$ .

Follow-up ANOVAs revealed significant main effects of Knowledge for participants tested Together,  $F(2, 58) = 14.5, p < .001, MSE = 5.86, \eta_p^2 = .334$ , and Separately,  $F(2, 62) = 5.6, p = .006, MSE = 2.39, \eta_p^2 = .153$ . Post hoc t-tests revealed that: SCR CIT effects were larger for Exclusively known items, compared to Unknown items and this difference occurred both for participants tested Together,  $t(29) = 2.54, p = .017, d = .463 (MD = .420)$ , and Separately,  $t(31) = 3.0, p = .005, d = .530 (MD = .545)$ ; SCR CIT effects were larger overall for Shared items, compared to Exclusively known item, but this only occurred for participants that were tested Together,  $t(29) = 2.7, p = .011, d = .493 (MD = .463)$ , with no significant difference for participants tested Separately,  $t(31) = 1.45, p = .159, d = .255 (MD = .240)$ . SCR CIT effects were larger for Shared items, when participants were tested Together compared to Separately,  $t(60) = 3.71, p < .001, d = .940 (MD = .585)$  but there was no significant difference in SCR CIT effects for participants tested Together or Separately for either Exclusive or Unknown knowledge items, ( $ps > .5$ ). Note that, collapsed over exclusive and shared knowledge, the CIT effect for SCR was large when participants were tested separately ( $d = .958$ ) or together ( $d = 1.61$ ).

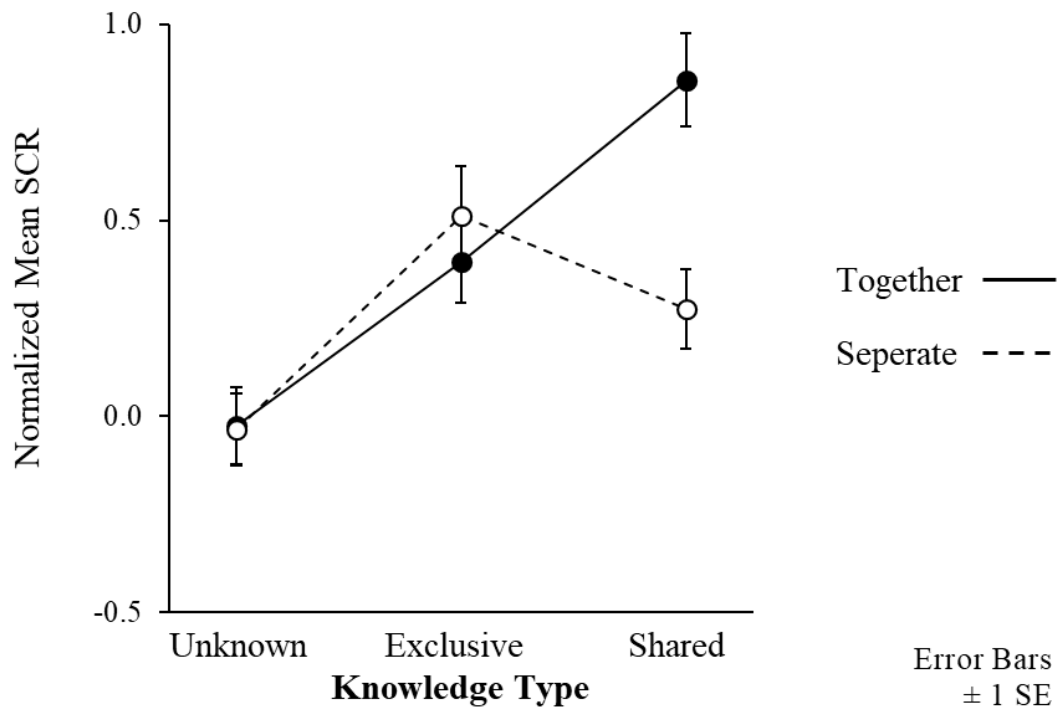


Figure 3.6. Experiment 2 - Mean normalized SCR CIT effect as a function of Knowledge Type and Testing condition.

### Heart Rate Change

The key finding was that there was no significant interaction between Knowledge and Testing although, overall participant's  $\Delta$ HR CIT effect was larger Shared knowledge items compared to Unknown items. As for the SCR analysis, mean normalized  $\Delta$ HR CIT effects were analyzed using a 2 (Tested: Together vs. Separate) x 3 (Knowledge: Unknown vs. Exclusive vs. Shared) mixed-ANOVA with Knowledge as the within-subjects factor (Figure 3.7). This revealed a main effect of Knowledge,  $F(2, 112) = 5.69, p = .004, MSE = 1.98, \eta_p^2 = .092$ ; but not Testing,  $F(1, 56) = .897, p = .348, MSE = .226, \eta_p^2 = .016$ . There was no significant two-way interaction between: Knowledge and Testing,  $F(1, 112) = 1.0, p = .370, MSE = .348, \eta_p^2 = .018$ . Collapsed over Testing, post hoc t-tests revealed that the  $\Delta$ HR CIT effects were larger for Shared and Exclusive items compared with unknown items,  $t(57) = 3.1, p = .003, d = .423 (MD = .346)$  and  $t(58) = 2.5, p = .015, d = .314 (MD = .268)$

respectively. No further comparisons for  $\Delta$ HR CIT effect were significant, ( $ps > .3$ ).

Note that, collapsed over exclusive and shared knowledge, the CIT effect for  $\Delta$ HR was large ( $d = .757$ ).

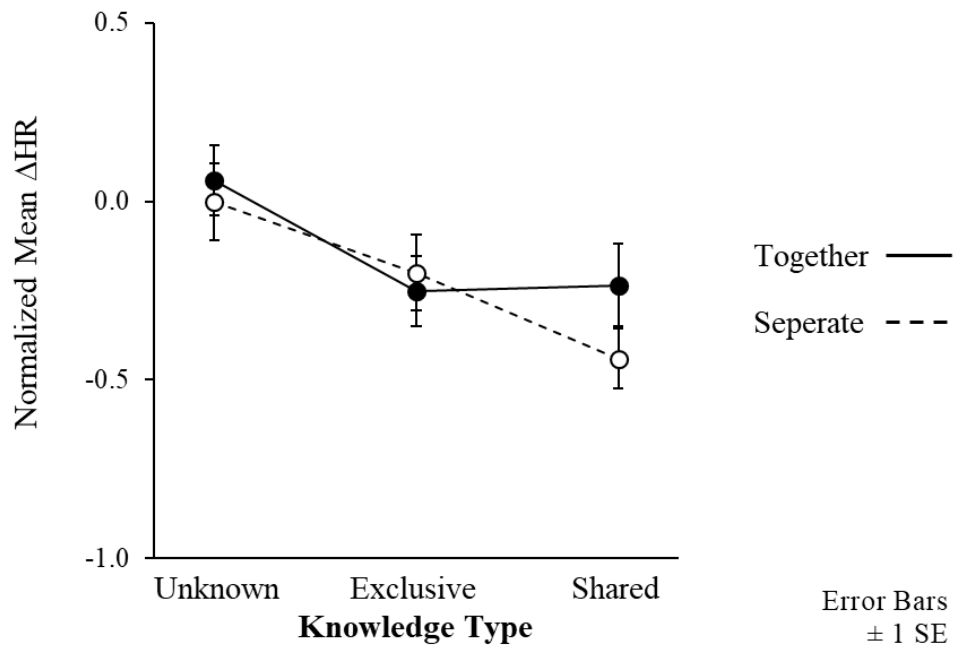


Figure 3.7. Experiment 2 - Mean normalized  $\Delta$ HR CIT effect as a function of Knowledge Type and Testing condition.

### Post CIT Questionnaire

Participants correctly recalled 96.6% of crime items, with 13 participants forgetting one of the six crime items. Overall participant self-reported motivation was moderate with Mean = 5.1,  $SD = 0.8$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>), with no difference between Testing conditions,  $t(62) = .738$ ,  $p = .463$ , ( $MD = .156$ ). Overall, participants' self-reported stress during the CIT was low with Mean = 3.4,  $SD = 1.2$  (range = 1<sub>no stress</sub> to 6<sub>highly stressed</sub>), with no difference between Testing conditions,  $t(62) = .701$ ,  $p = .486$ , ( $MD = .216$ ). Participants rated the mock crime videos as immersive with Mean = 4.5,  $SD = 1.1$  (range = 1<sub>not immersive</sub> to 6<sub>highly immersive</sub>). Thirty participants (47%), reported using some form of countermeasure to fool the test: six gave special attention to the control items; six thought about something else; six

remained calm; six tried to control their breathing; two tried to control their heart rate; two actively tried to suppress memory of the crime items; one bit their tongue; and one tried randomly twitching. The difference between the number of participants attempting countermeasures when tested Together (56%) or Separately (38%) was non-significant,  $\chi^2(1, N = 64) = 2.3, p = .132$ . In sum, self-reported motivation to beat the CIT, stress during the CIT and the use of countermeasures did not differ between groups suggesting that these factors are unlikely to have significantly influenced the above findings.

### **Order Factor Check**

Participants tested Separately were either tested before or after their partner and this was counterbalanced. To check for order effects, mean normalized SCR and  $\Delta$ HR CIT effects were analyzed using a 2 (Order: First vs. Second) x 3 (Knowledge: Unknown vs. Exclusive vs. Shared) mixed-ANOVA with Knowledge as the within-subjects factor. There was no main effect of Order for SCR,  $F(1, 30) = .384, p = .540, MSE = .111, \eta_p^2 = .013$ , or for  $\Delta$ HR,  $F(1, 27) = 1.18, p = .286, MSE = .294, \eta_p^2 = .042$ . There was also no interaction between Order and Knowledge for SCR,  $F(2, 60) = .440, p = .646, MSE = .191, \eta_p^2 = .014$ , or for  $\Delta$ HR,  $F(2, 54) = 1.16, p = .321, MSE = .381, \eta_p^2 = .041$ . This suggests that the order that participants were tested separately had no impact on the findings.

## Discussion

In the current experiment we investigated whether the CIT efficiency differed for pairs who, after committing a crime collaboratively, took the CIT together. Specifically, the impact of group testing for knowledge shared between partners, was of interest. Participants watched mock crime videos encoding both *Shared* information and information encoded individually (*Exclusively*) that the other partner had no knowledge of (*Unknown*). Pairs then underwent a physiological CIT either in the same room simultaneously (i.e. *Together*) or one at a time (*Separately*). SCR and  $\Delta$ HR CIT effects were analyzed.

The key finding was that participants' SCR CIT effect was larger for shared compared to exclusive knowledge, but this was only the case when participants were tested together. For participants tested separately, no difference was found between shared and exclusive knowledge. The CIT effects for both groups were large with no CIT effect present when participants did not recognize the unknown items (as only their partner had knowledge of these). However, the same pattern of results was not found for  $\Delta$ HR where no significant interaction between Knowledge and Testing was found. The overall  $\Delta$ HR CIT effect was larger for shared knowledge items compared to unknown items. There was no difference between self-reported motivation, stress and countermeasure use across both testing conditions, suggesting these factors could not account for the above findings. Additionally, there was no difference between CIT effects for participants that underwent the CIT first or second when tested separately.

The finding that the CIT effect is larger for shared knowledge when a partner is present appears to partially align with theories of Encoding Specificity. However, in this experiment, no difference was found between shared and exclusive knowledge

when participants were tested separately. Collaborative inhibition findings, such as that found in a previous P300 CIT experiment ([Lu et al., 2018](#)), suggested that participants responding to shared items, when tested separately, should show a reduced CIT effect compared to exclusive items. However, this was not found in the current experiment. A direct replication of this experiment was planned to corroborate these novel findings and to increase power to allow for further investigation of the null collaborative inhibition finding.

### **Experiment 3 – Replication of Experiment 2**

In Experiment 2, we found that participants' SCR CIT effect was larger for shared compared to exclusive knowledge, but this was only the case when participants were tested together. No such effect was found for the  $\Delta$ HR CIT effect. To check the reliability of these findings, Experiment 3 replicated Experiment 2 with only minor differences to the sample recruited. To avoid the issue of unbalanced groups in the SCR analysis and reduced power, due to SCR non-responders, participants were incrementally recruited until thirty-six SCR responders were tested in each group. Furthermore, participants were all undergraduate psychology students and received course credit for taking part instead of a monetary payment. All other aspects of the method were the same. Finally, a combined analysis using data from both Experiments 2 and 3 was planned to follow this replication.

#### **Method**

##### **Participants**

Eighty-four participants (77 women), aged between 18 - 22 years (*Mean* = 18, *SD* = 0.7) took part for course credit towards their first year undergraduate Psychology degree at the authors' institution. Participants received no payment for partaking in the 50-minute testing session but did receive the opportunity to receive their 'lie detection score' as well as a £25 Amazon voucher each if their pair obtained the best score. Participants were equally split and allocated in an alternating fashion between either the paired or the separate condition until each Testing condition reached thirty-six SCR responders (this resulted in forty-four participants being tested in the Together group and forty in the Separate group). As this was a replication of the previous experiment, with the exception of participant demographics, the remaining methodology was identical to Experiment 2.



### Exclusions

Out of all possible trials, thirteen (0.34%) were removed from analysis due to large movement artifacts: six posture shifts; five large head movements; one chair swivels and one cough. In total, eleven (13%) participants were considered SCR non-responders and their data were excluded from the SCR analysis (seven in the Together condition). One participants' heart rate data were excluded from the analysis due to dislodged sensors. Finally, due to a technical error data was not recorded for the last two CITs for two participants and for the first trial for two participants.

### Results

#### Skin Conductance Responses

The key finding was that, like the findings from Experiment 2, participant's SCR CIT effect was larger for items that participants both encoded (i.e. the Shared knowledge) compared to items that participants encoded Exclusively, but this was only when participants were tested Together.

Mean normalized SCR CIT effects were analyzed using a 2 (Tested: Together vs. Separate) x 3 (Knowledge: Unknown vs. Exclusive vs. Shared) mixed-ANOVA with Knowledge as the within-subjects factor (Figure 3.8). This revealed a significant main effect of Knowledge,  $F(2, 140) = 34.6, p < .001, MSE = 10.8, \eta_p^2 = .330$ ; but not Testing,  $F(1, 70) = 1.32, p = .255, MSE = .485, \eta_p^2 = .018$ . There was also a significant two-way interaction between Knowledge and Testing,  $F(1, 140) = 4.85, p = .009, MSE = 1.51, \eta_p^2 = .065$ . Follow-up ANOVAs revealed a significant main effect of Knowledge for participants tested Together,  $F(2, 70) = 19.4, p < .001, MSE = 7.04, \eta_p^2 = .356$ , and Separately,  $F(2, 70) = 20.2, p < .001, MSE = 5.26, \eta_p^2 = .366$ .

Post hoc t-tests revealed that: SCR CIT effects were larger for Exclusively known items, compared to Unknown items, for participants tested Together,  $t(35) = 3.94, p = .001, d = .657$  ( $MD = .515$ ), and Separately,  $t(35) = 5.85, p < .001, d = .974$  ( $MD = .741$ ); SCR CIT effects were larger for Shared items, compared to Exclusively known items, but only for participants tested Together,  $t(35) = 2.47, p = .018, d = .412$  ( $MD = .365$ ), with only a marginal difference for participants tested Separately,  $t(35) = 1.89, p = .067, d = .315$  ( $MD = .210$ ); SCR CIT effects for Shared knowledge items were larger for participants tested Together compared to Separately,  $t(70) = 2.54, p = .013, d = .599$  ( $MD = .403$ ), and finally there was no significant difference between SCR CIT effect for either Exclusive or Unknown Knowledge items, ( $ps > .25$ ). Note that, collapsed over exclusive and shared knowledge, the CIT effect for SCR was large when participant when tested together ( $d = .957$ ) but smaller when tested separately ( $d = .685$ ).

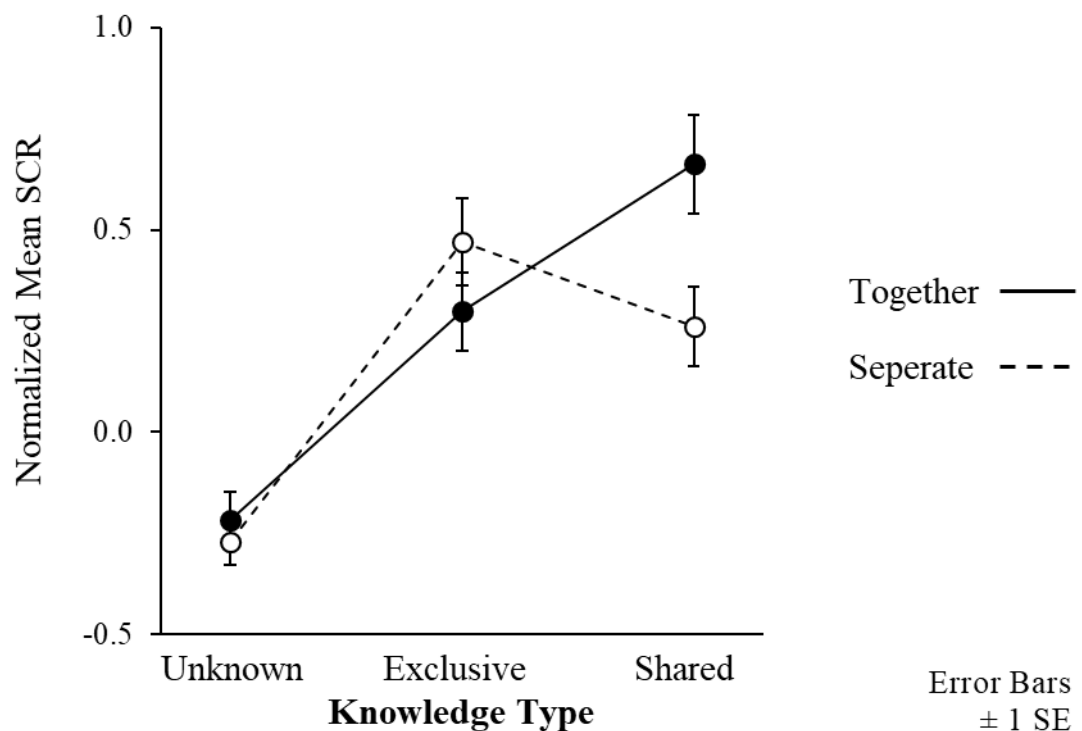


Figure 3.8. Experiment 3 - Mean normalized SCR CIT effect as a function of Knowledge Type and Testing condition.

### Heart Rate Change

Similar to Experiment 2, the key finding was that there was no interaction between Knowledge and Testing on the  $\Delta$ HR CIT effect. Mean normalized  $\Delta$ HR CIT effects were analyzed using a 2 (Tested: Together vs. Separate) x 3 (Knowledge: Unknown vs. Exclusive vs. Shared) mixed-ANOVA with Knowledge as the within-subjects factor (Figure 3.9). This revealed a significant main effect of Knowledge,  $F(2, 162) = 9.03, p < .001, MSE = 2.97, \eta_p^2 = .100$ , but not of Testing,  $F(1, 81) = .223, p = .638, MSE = .070, \eta_p^2 = .003$ . There were no significant two-way interactions between: Knowledge and Testing,  $F(1, 162) = .210, p = .811, MSE = .069, \eta_p^2 = .003$ .

Post hoc t-tests, collapsed over Testing conditions, revealed that the  $\Delta$ HR CIT effects were larger for Exclusive items than Unknown items,  $t(82) = 3.62, p = .001, d = .398 (MD = .343)$ , and larger for Shared items than Unknown items,  $t(82) = 3.62, p < .001, d = .397 (MD = .314)$  but there was no significant difference in  $\Delta$ HR CIT effect between Exclusive and Shared items  $t(82) = .351, p = .726, d = .039 (MD = .029)$ . Note that, collapsed over exclusive and shared knowledge, the CIT effect for  $\Delta$ HR was medium ( $d = .643$ ).

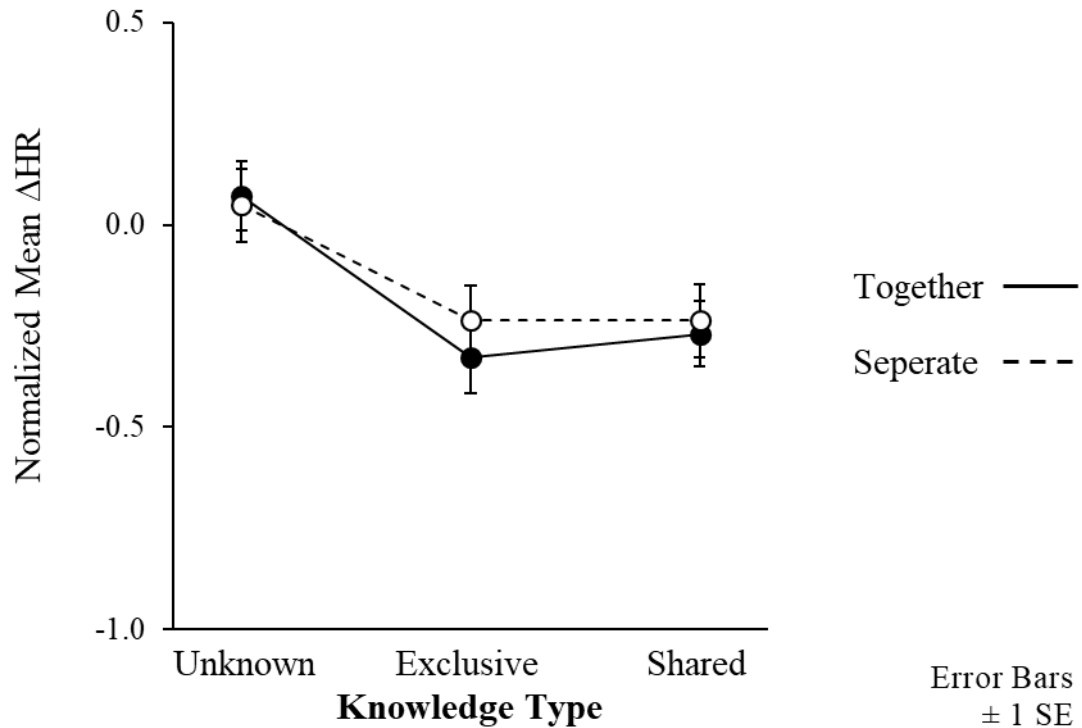


Figure 3.9. Experiment 3 - Mean normalized  $\Delta$ HR CIT effect as a function of Knowledge type and Testing condition.

### Post CIT Questionnaire

Participants correctly recalled 99.6% of crime items, with 2 participants forgetting one of the six crime items. Overall, participants' self-reported motivation was moderate with Mean = 5.0,  $SD = 0.8$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>), with no difference between Testing conditions,  $t(82) = .662$ ,  $p = .510$ , ( $MD = .116$ ). Overall, participant's self-reported stress during the CIT was low, with Mean = 3.0,  $SD = 1.3$  (range = 1<sub>no stress</sub> to 6<sub>highly stressed</sub>), with no difference between Testing conditions,  $t(82) = .670$ ,  $p = .505$ , ( $MD = .186$ ). Participants rated the mock crime videos as immersive with Mean = 4.4,  $SD = .88$  (range = 1<sub>not immersive</sub> to 6<sub>highly immersive</sub>). Twenty-eight participants (33%), reported using some form of countermeasure to fool the test: thirteen tried to control their breathing, four thought about something else, four tried to control their heart rate, three remained calm, and two tried to control both

their heart rate and breathing. The difference between the number of participants attempting countermeasures when tested Together (30%) or Separately (38%) was non-significant,  $\chi^2(1, N = 84) = .597, p = .440$ . In the same way as Experiment 2, self-reported motivation to beat the CIT, stress during the CIT, and the use of countermeasures did not differ between groups, suggesting that these factors are unlikely to have significantly influenced the findings.

### **Order Factor Check**

Participants tested Separately were either tested before or after their partner and this was counterbalanced. To check for potential order effects, mean normalized SCR and  $\Delta$ HR CIT effects were analyzed using a 2 (Order: First vs. Second) x 3 (Knowledge: Unknown vs. Exclusive vs. Shared) mixed-ANOVA with Knowledge as the within-subjects factor. There was no main effect of Order for SCR,  $F(1, 34) = .031, p = .860, MSE = .012, \eta_p^2 = .001$ , or  $\Delta$ HR,  $F(1, 38) = 2.46, p = .125, MSE = .876, \eta_p^2 = .061$ . There was also no interaction between Order and Knowledge for SCR,  $F(2, 68) = .558, p = .575, MSE = .147, \eta_p^2 = .016$ , and  $\Delta$ HR,  $F(2, 76) = .014, p = .986, MSE = .004, \eta_p^2 \approx 0$ . This again suggested that the order that participants were tested separately had no impact on the findings.

### **Discussion**

This experiment was a replication of Experiment 2 and revealed similar results. Namely, the SCR CIT effect was larger for shared compared to exclusive knowledge, but only when participants were tested together. This was not found for heart rate however as the  $\Delta$ HR CIT. Note the main difference here was that the  $\Delta$ HR CIT also differed between crime details encoded individually compared to crime details not seen i.e. unknown items. Again, there was no difference between self-

reported motivation, stress and countermeasure use across both testing conditions and no difference in results between participant partners that underwent the CIT first or second in the separate CIT testing condition. As planned, data from Experiment 2 and 3 were next combined to determine the consistency in these findings and to allow a signal detection analysis.

### Combined Analysis

#### Skin Conductance Responses

The key finding from this combined analysis was that that participants' SCR CIT effect was smaller for items that participants both encoded (i.e. Shared knowledge) compared to items that participants encoded Exclusively, but this was only for participants tested Separately. Furthermore, the overall SCR CIT effect was larger in Experiment 2 than 3.

Mean normalized SCR CIT effects were analyzed using a 2 (Experiment: First vs. Replication) x 2 (Tested: Together vs. Separate) x 3 (Knowledge: Unknown vs. Exclusive vs. Shared) mixed-ANOVA with Knowledge as the within-subjects factor (Figure 3.10). This revealed: a significant main effects of Experiment,  $F(1, 130) = 9.72, p = .002, MSE = 3.19, \eta_p^2 = .070$ , indicating SCR CIT effects overall were smaller in the replication experiment; there was a main effect of Knowledge,  $F(2, 260) = 45.7, p < .001, MSE = 16.4, \eta_p^2 = .260$ , and Testing,  $F(1, 130) = 4.85, p = .029, MSE = 1.60, \eta_p^2 = .036$  where the CIT effect was larger overall when participants were tested together. There was a significant two-way interaction between Knowledge and Testing,  $F(2, 260) = 10.1, p < .001, MSE = 3.63, \eta_p^2 = .072$ , but no significant interaction between Knowledge and Experiment,  $F(2, 260) = .537, p = .586, MSE = .193, \eta_p^2 = .004$ , nor between Experiment and Testing,  $F(1, 130) = .303, p = .583, MSE = .100, \eta_p^2 = .002$ . Finally, the three-way Experiment, Knowledge and Testing interaction was non-significant,  $F(2, 260) = .304, p = .738, MSE = .109, \eta_p^2 = .002$ .

Given no interaction effects between Experiments 2 and 3, mean normalized SCR CIT effects were combined and analyzed using a 2 (Tested: Together vs. Separate) x 3 (Knowledge: Unknown vs. Exclusive vs. Shared) mixed-ANOVA with

Knowledge as the within-subjects factor. This revealed a significant main effect of Knowledge,  $F(2, 264) = 46.9, p < .001, MSE = 16.7, \eta_p^2 = .262$ , and Testing,  $F(1, 132) = 4.23, p = .042, MSE = 1.47, \eta_p^2 = .031$  where the CIT effect was larger overall when participants were tested together. There was also a significant two-way interaction between: Knowledge and Testing,  $F(1, 264) = 10.1, p < .001, MSE = 3.59, \eta_p^2 = .071$  (Figure 3.10).

Follow-up ANOVAs revealed a significant main effect of Knowledge for participants tested Together,  $F(2, 130) = 34.1, p < .001, MSE = 12.8, \eta_p^2 = .344$ , and Separately,  $F(2, 134) = 21.9, p < .001, MSE = 7.39, \eta_p^2 = .247$ . Post hoc t-tests revealed that: SCR CIT effects were larger for Exclusively known items, compared to Unknown items, both for participants tested Together,  $t(65) = 4.58, p < .001, d = .564 (MD = .472)$ , and Separately,  $t(67) = 5.98, p < .001, d = .725 (MD = .649)$ ; SCR CIT effects were larger for Shared items, compared to Exclusively known items, but only for participants tested Together,  $t(65) = 3.68, p < .001, d = .453 (MD = .410)$ , and SCR CIT effects were smaller for Shared items, compared to Exclusively known items for participants tested Separately,  $t(67) = 2.31, p = .024, d = .280 (MD = .224)$ ; SCR CIT effects for Shared items, were larger for participants tested Together compared to Separately,  $t(132) = 4.31, p < .001, d = .744 (MD = .484)$  and; finally there was no significant difference in SCR CIT effects for participants tested Together or Separately for either Exclusive or Unknown Knowledge items, ( $ps > .2$ ). Note that, collapsed over exclusive and shared knowledge, the CIT effect for SCR was large when participants were tested separately ( $d = .806$ ) and together ( $d = 1.20$ ).



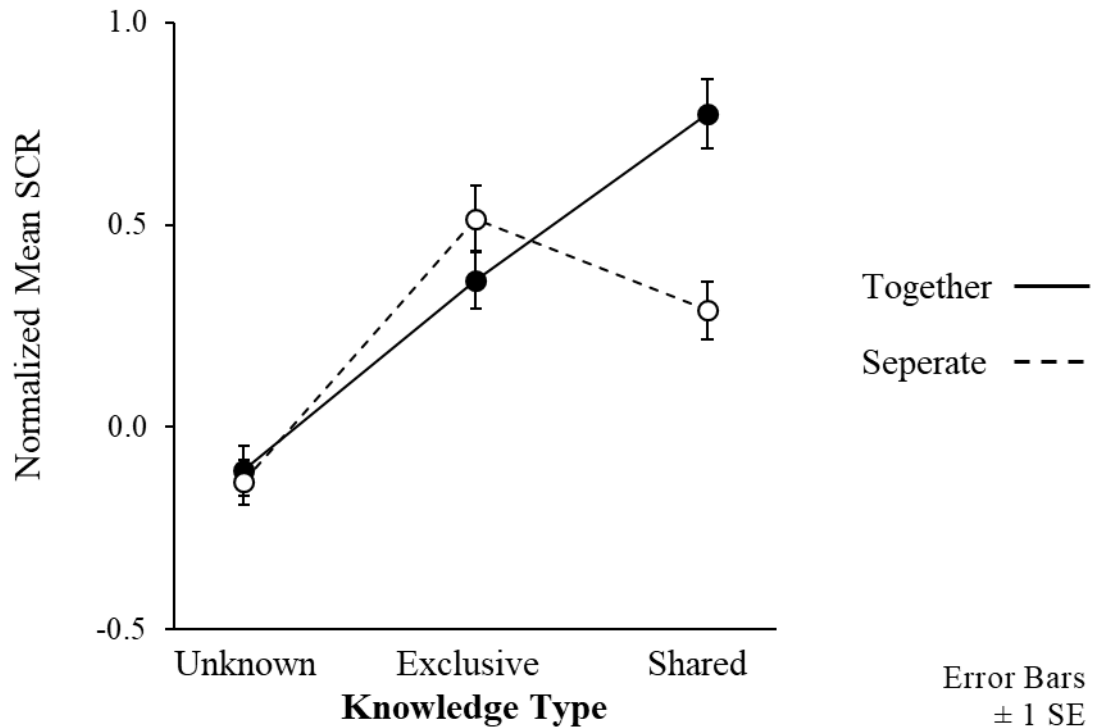


Figure 3.10. Experiments 2 and 3 combined mean normalized SCR CIT effect as a function of Knowledge type and Testing condition.

### Heart Rate Change

The key findings were that there was no interaction between Knowledge and Testing and no difference between Exclusive and Shared knowledge. Mean normalized  $\Delta$ HR CIT effects were analyzed using a 2 (Experiment: First vs. Replication) x 2 (Tested: Together vs. Seperate) x 3 (Knowledge: Unknown vs. Exclusive vs. Shared) mixed-ANOVA with Knowledge as the within-subjects factor (Figure 3.11). This revealed a significant main effect of Knowledge,  $F(2, 274) = 13.8, p < .001, MSE = 4.65, \eta_p^2 = .092$ ; but not Experiment,  $F(1, 137) = .140, p = .709, MSE = .041, \eta_p^2 = .001$ ; or Testing,  $F(1, 137) = .132, p = .717, MSE = .038, \eta_p^2 = .001$ . There was no significant two-way interaction between Experiment and Testing,  $F(1, 137) = .989, p = .322, MSE = .286, \eta_p^2 = .007$ ; or Knowledge and Experiment,  $F(2, 274) = .344, p = .709, MSE = .116, \eta_p^2 = .003$ , or Knowledge and

Testing,  $F(2, 274) = .897, p = .409, MSE = .302, \eta_p^2 = .007$ . Finally, there was no significant three-way interaction between Experiment, Knowledge and Testing,  $F(2, 274) = .489, p = .614, MSE = .164, \eta_p^2 = .004$ . Post hoc t-tests, collapsed over Testing conditions, revealed that the  $\Delta HR$  CIT effects were larger for Exclusive items than unknown items,  $t(140) = 4.41, p < .001, d = .424 (MD = .312)$ , and larger for Shared items than unknown items,  $t(140) = 4.80, p < .001, d = .367 (MD = .330)$  but there was no significant difference in  $\Delta HR$  CIT effect between Exclusive and Shared items  $t(140) = .424, p = .672, d = .050 (MD = .028)$ . Note that, collapsed over exclusive and shared knowledge, the CIT effect for  $\Delta HR$  was medium ( $d = .689$ ).

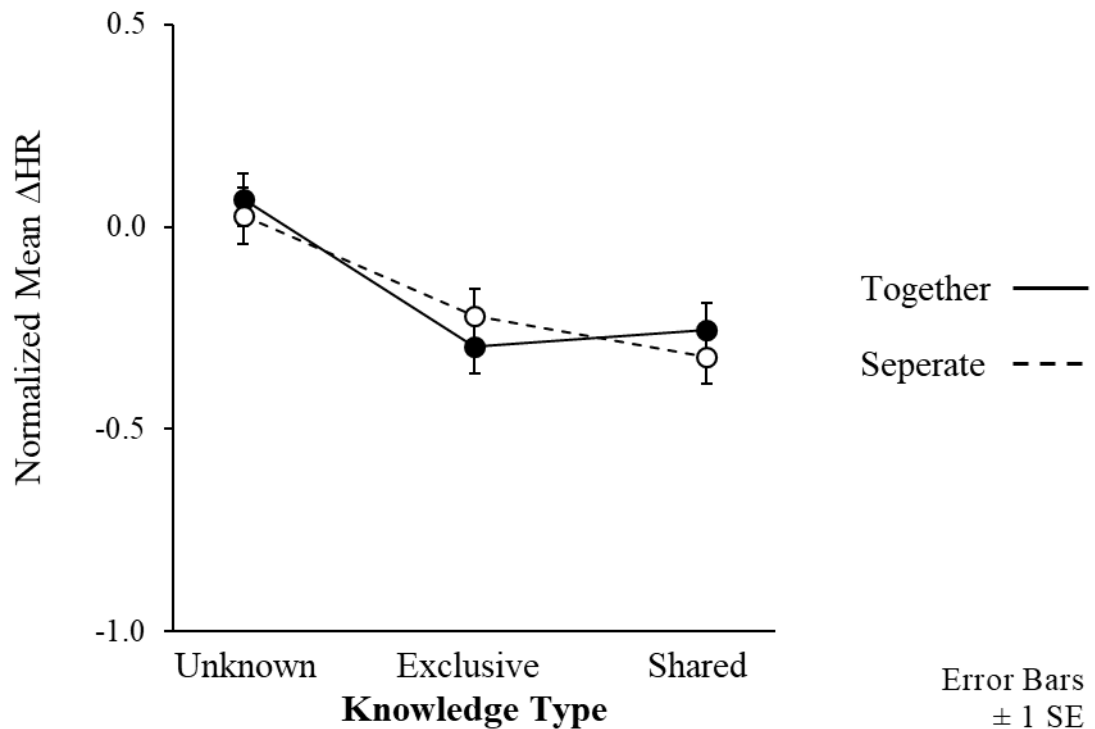


Figure 3.11. Experiments 2 and 3 combined mean normalized  $\Delta HR$  CIT effect as a function of Knowledge type and Testing condition.

### Signal Detection Analysis

To assess the efficiency of detection, signal detection analysis was used to determine the degree of separation between the participants in our experiment who were considered ‘guilty’ and an equivalent innocent group. Given no innocent participants were tested, data for innocent participants were simulated by the standard method used in the CIT literature (e.g. [Carmel, Dayan, Naveh, Raveh, & Ben-Shakhar, 2003](#); [Visu-Petra et al, 2013](#); and [Meijer, Smulders, Johnston, & Merckelbach, 2007](#)). This approach assumes that innocent participants, not knowledgeable about the crime item, respond in the same manner to all items. Therefore, the procedure for simulating innocent participant data involves drawing random SCRs from a standard normal distribution. This is conducted for each trial with one trial in five then randomly chosen to represent the simulated crime item. Once calculated for each participant, an ROC was generated to approximate the signal detection using within-subject scored CIT effect for the ‘guilty’ group and for the normalized simulated ‘innocent’ group. ROCs are based on a comparison of two detection score distributions, where detection score of guilty was defined as the mean normalized difference between crime and control items and the detection score of innocents was similarly defined but using the simulated crime and control responses.

As shown in [Figure 3.12](#), the curves are close to the upper left-hand corner of the ROC which indicates a high overall accuracy ([Zweig & Campbell, 1993](#)). The area under this curve (*AUC*) allows an objective measure of the accuracy trade-off between the test sensitivity and specificity. An *AUC* = 0.5 suggests no discrimination (i.e. chance level), 0.7-0.8 is considered fair, 0.8-0.9 is considered excellent, and 0.9+ is considered outstanding ([Hosmer Jr, Lemeshow, & Sturdivant, 2000](#)). When the crime was committed collaboratively, regardless of whether the information was

shared or not, the diagnosticity was greater when those participants were tested Together ( $AUC = .827$ ,  $d = 1.15$ ) compared to Separately ( $AUC = .729$ ,  $d = .821$ ) ( $AUC\ diff = .098$ ,  $SE = .04$ ,  $z = 2.46$ ,  $p = .014$ ). However, compared to individually testing participants ( $AUC = .793$ ,  $d = .99$ ) who committed the crime individually (i.e. participants in Experiment 1), diagnosticity did not differ between participants tested together ( $AUC\ diff = .034$ ,  $SE = .049$ ,  $z = .696$ ,  $p = .486$ ) or separately ( $AUC\ diff = .064$ ,  $SE = .052$ ,  $z = 1.23$ ,  $p = .220$ ) in Experiments 2 and 3.

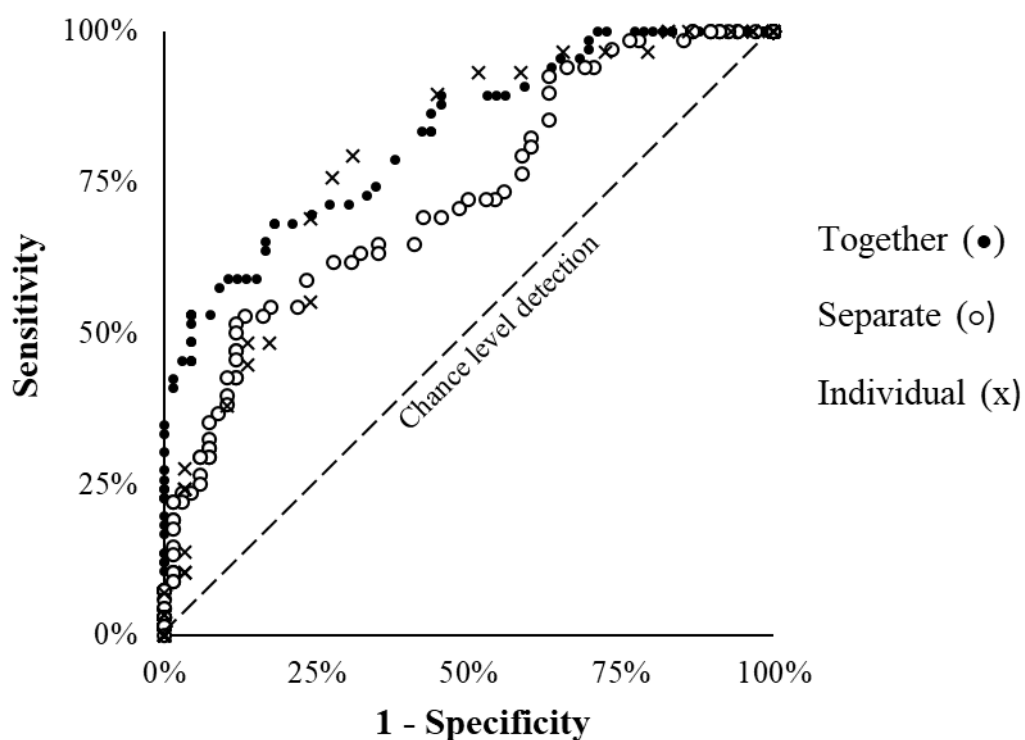


Figure 3.12. Experiments 2 and 3 combined - Signal detection curve (ROC) showing the detection sensitivity and specificity between guilty and simulated innocent participants for SCR when participants were tested separately (o) or together (●) in Experiments 2-3 following a collaborative mock crime. Additionally, the signal detection curve for participants tested individually (x) following a solo mock crime (in Experiment 1) is provided as a baseline.

### **General Discussion Part 1.**

High profile criminal activity is often planned and carried out by groups of people each having individual roles and information about the crime. The group CIT has been proposed as a method for extracting critical information from criminal groups (Bradley & Barefoot, 2010; Breska, Ben-Shakhar, & Gronau, 2012; Breska et al., 2014; Elaad, 2016; Meijer et al., 2010; and Meijer et al., 2013). Here we present the first study to test the effects of group vs individual CIT testing and its impact on the CIT effect for shared and non-shared crime information.

This study examined whether the CIT effect (SCR and  $\Delta$ HR) differed for pairs who took the CIT together after committing a crime collaboratively compared with individual testing. Specifically, the impact of group testing for both knowledge shared between partners and not shared was of interest. Participant pairs watched two mock crime videos, filmed and subsequently played back, from a 1<sup>st</sup> person perspective of two thieves carrying out a heist together. During the heist the thieves encountered crime information together as indicated by the presence of the thief representing the participant's partner visible in the video. Participants also saw crime details that their partner did not know, thereby making those details exclusive knowledge for one but unknown information for the other. Given the linearly constructed narrative of the mock crime videos, Experiment 1 was conducted to check that the crime details in each knowledge category did not differ - they did not. Participant pairs then underwent a CIT either in the same room together or individually, one at a time - this order was counterbalanced and found to have no effect. Experiment 2 was replicated with similar findings revealed; then all data were combined for further analysis. Across both Experiments 2 and 3, the SCR CIT effect was larger for shared compared to exclusive knowledge, but only when participants

were tested together. Additionally, the combined analysis revealed that the SCR CIT effect was smaller for shared compared to exclusive knowledge, but only when participants were tested separately. This reverse effect, smaller CIT effect to shared items when tested together, was not present in Experiment 2 and marginal in Experiment 3.

Encoding and retrieving memories in groups differ from when done alone as individuals. For example, the term collaborative inhibition is given to the finding that groups asked to recall information encoded collaboratively perform worse than groups that encoded the information individually (Marion & Thorley, 2016).

Although studies do not typically find this effect with recognition tasks (Blumen & Rajaram, 2009), a study by Lu and colleagues (2017) found that the P300 amplitude CIT effect was smaller when participants collaboratively encoded the mock crime information in pairs (note participants in Lu's study only underwent the CIT individually). A similar result was found in the current study as participants tested separately showed a smaller SCR CIT effect for shared knowledge items compared to items encoded individually. However, the results of the current study are unlikely to be due to collaborative inhibition.

The CIT is a recognition task, where all participants are cued by the stimulus thereby negating any benefit of using individual retrieval strategies for both participants tested together and separately (Basden, Basden, Bryner, & Thomas, 1997). Further, the Transactive Memory theory proposes that responsibility for encoding group information is shared and divided between members (Hollingshead & Brandon, 2003). However, in the current experiments this is unlikely to have occurred because participants were instructed to watch two mock crime videos and remember as much as possible. Therefore, responsibility for encoding the shared

crime information is unlikely to have been divided. Instead of using collaborative inhibition to explain our findings, a simpler alternative explanation appears to better account for the pattern of results. Encoding Specificity ([Tulving & Thomson, 1973](#)) suggests that people encoding and retrieving information alone benefit from both context-dependent learning and transfer-appropriate processing whereas for people encoding individually but retrieving in a group suffers due to a mismatch ([Barber, Rajaram & Aron, 2010](#)). Indeed, this is what was found in our study, suggesting Encoding Specificity can account for these SCR findings.

Interestingly, when data were combined over Experiments 2 and 3, there was no such interaction between testing and knowledge for the  $\Delta$ HR CIT effect and no overall effect of testing. The heart rate data consistently showed different patterns of results compared to SCR across both experiments. Initially, researchers theorized that both SCR and heart rate measured orienting-based recognition, however, evidence that heart rate changes in the CIT are related to orienting is less clear ([klein Selle, Verschuere & Ben-Shakhar, 2018](#)). Response fractionation theory attempts to explain why SCR and heart rate change (along with other parasympathetic measures such as respiration variability) do not always correlate ([Verschuere, Meijer, & De Clercq, 2011](#)). This theory postulates that whilst SCRs are related to recognition via orienting processes, heart rate change is better accounted for by arousal inhibition experienced when actively concealing and suppressing recognition of items (see also [klein Selle et al., 2016](#); [klein Selle, Verschuere, Kindt, Meijer, & Ben-Shakhar, 2017](#)). The data in our study provide further support for fractionation theory and suggest that group testing does not affect arousal inhibition.

Previous research has demonstrated that motivation to beat the CIT ([Ben-Shakhar & Elaad, 2003](#)), stress during testing ([Verschuere et al., 2011](#)) and

countermeasure use can all impact the CIT. However, no significant differences in self-reported ratings of motivation, stress or countermeasure used were found between groups in this study i.e. those given a CIT together or separately. This suggests that these factors cannot account for the present findings. Similarly, there was also no difference between participant partners that underwent the CIT separately first or second, indicating that order was not important.

In sum, this is the first study to consider the potential effects of testing crime partners together, with both shared and exclusive knowledge, in the CIT. We found that concealed recognition is stronger for crime items known by both suspects when they both encoded and retrieve the crime details together. Based on these findings it could be recommended that when a crime is committed by pairs of suspects who are exposed to differing amounts of information, a group CIT should be conducted with suspects tested together simultaneously. This follows because the detection of concealed information was greater when participants were tested together ( $AUC = .827$ ) compared to separately ( $AUC = .729$ ). However, outside of the lab paired CIT testing is risky as suspects could willingly influence or distract each other in an effort to fool the test. The effects of such actions are currently unknown and therefore, at present group CIT testing is not advised. Indeed, this study demonstrates that group testing can impact suspect's responding in the CIT. Further work would be useful to validate and generalize the current findings to scenarios with increased ecological validity (e.g. real-world collaborative mock crime tasks such as in [Lu et al., 2018](#)) and across different labs. Nonetheless, our initial findings are useful for those investigating group-based CIT testing as a method for extracting information using a searching CIT approach.





## PART 2. REACTION TIME MEASURES

### Experiment 4: Paired RT-CIT Check

In Part 1 of this chapter, the recognition-based (SCR) CIT effect was found to be larger when suspect pairs viewed crime items together following collaborative encoding. This translated into a greater detection of concealed information from participant pairs when the pairs were tested together. Part 1 was the first study to attempt to experimentally determine the effects of group testing and shared knowledge in the physiological CIT. Such findings provide important theoretical and practical insights into group CIT testing. Given the positive results found in Part 1, it was important to establish whether the results in the physiological CIT apply to the RT-CIT. To the authors' knowledge, no study has tested the efficiency and effects of group RT-CIT testing.

The reaction time CIT (RT-CIT), already described in Chapter 2 of this thesis, is recapped here. The RT-CIT is designed to determine whether a suspect is concealing privileged knowledge of hidden crime information that only the culprit would recognize ([Ben-Shakhar & Elaad, 2003](#)). However, the RT-CIT measures reaction times rather than physiological responses (e.g. SCR and  $\Delta$ HR) as a way of detecting concealed recognition (for a review see [Verschuere, Suchotzki, & Debey, 2014](#)). As an oddball task, participants respond using a keyboard, to a sequence of briefly presented stimuli containing crime, control and target items. The crime and control items are the same as those used in physiology CITs. Participants, therefore, respond 'no' to indicate that they do not recognize either the crime or the control items. Target items however are specially required for the RT-CIT and consist of a set of images that the participant is shown before the test and are instructed to respond 'yes' to. Targets items ensure that participants are attending to each stimulus.

Following a question such as “do you recognize this item as relating to the crime?”, guilty suspects in the RT-CIT respond ‘No’ (untruthfully) more slowly to crime items than they respond ‘No’ (truthfully), to control items. This response inhibition (slowing) is argued to be due to participants attempting to resolve the conflict between actually recognizing the crime item and yet reporting that they do not (Debey, Ridderinkhof, De Houwer, De Schryver, & Verschuere, 2015). This conflict sometimes results in an increased number of errors as well such as pressing ‘Yes’ to the crime items or ‘No’ to the target items (Suchotzki et al., 2017). When testing individuals, the RT-CIT can be as diagnostic as the physiological-based CIT with excellent detection rates (Granhag, Vrij & Verschuere, 2015, p. 274).

Unlike the physiology-based CIT, there are no group RT-CIT studies reported in the literature. This may be because study of the RT-CIT is recent or because there is an expectation that a group RT-CIT would be less effective due to the disturbance caused by the presence on a partner. Any distractions by a partner during an RT-CIT would increase noise and potentially reduce the processing of the stimuli required for response inhibition to occur. Practically, like with the physiological CIT, there may be advantages to testing suspects in pairs when they have collaborated in either planning or conducting a crime. Testing suspect partners together may result in increased detection rates for the same reasons discussed above for the physiological CIT. Further, group testing methods could be used in a searching RT-CIT where the investigators are attempting to extract new information from a group of suspects (Bradley & Barefoot, 2010; Breska, Ben-Shakhar, & Gronau, 2012; Breska et al., 2014; Elaad, 2016; Meijer et al., 2010; and Meijer et al., 2013). Furthermore, the findings from group based RT-CIT may provide theoretical insights into the processes that modulate the RT-CIT or interfere with response inhibition.

Therefore, in Part 2 of this chapter, its tested whether the RT-CIT effect is present or negated during paired testing of suspects who are concealing recognition of autobiographic scenes (Experiment 4) before testing whether this group RT-CIT effect differs from when participants are tested separately (Experiment 5). Finally, the type of knowledge (Shared, Exclusive or Unknown) is introduced by replicating Experiments 2, i.e. using the pair mock crime videos, but with the RT-CIT (Experiment 6).

## **Method**

### **Participants**

Previous literature indicates that the RT-CIT effect (crime minus control items) is large ([Granhag, Vrij & Verschuere, 2015](#)). A power analysis using G\*Power ([Faul et al., 2007](#)), with a large effect size of  $d = .80$ , and  $\alpha = 0.05$  for a single group, suggested a minimum sample size of 19 subjects would be sufficient for a power of 0.95. Fifteen pairs, i.e. thirty participants (20 women), aged between 18-26 years ( $Mean = 20.0$ ,  $SD = 2.0$ ), signed up together through a University online participant panel at the authors' institution. Participants received £3 payment for taking part in the 30-minute testing session, the opportunity to receive their 'lie detection score' and a chance to win a £25 Amazon voucher each if their pair obtained the lowest score.

### Materials.<sup>3</sup>

The stimuli were photographs of scenes that typically contained landscapes, buildings, and other structures. The five autobiographic images ('crime' items), were images of various scenes of the participant's university campus. For each crime item, four matched control scene stimuli were sourced using Google's Reverse Image Search function with the crime items as reference images. In addition to the crime and control stimuli, five images of another University were used as target items. All images were open source, cropped to remove potential noise (e.g., people), were resampled to 1366 x 768 pixels and presented full-screen on a 21" LCD monitor, 16:9 aspect ratio at a resolution of 1920 x 1080 pixels. Participants sat approximately 40cm from the screen with the center of the screen at approximately eye level. Examples of stimuli used in Experiment 4 are shown in [Figure 3.13](#).



*Figure 3.13. Examples of control, crime and target scene images used in Experiment 1.*

### The CIT

The RT-CIT was made up of 450 images with 30 images (one block) repeated 15 times. Each block of 30 images contained five CITs and each CIT consisted of six images: a crime item, a target, and four control items. There was a short break of

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<sup>3</sup> Note that the Materials, CIT and Procedure were similar to those used in Experiment 1, Chapter 2 of this Thesis.

3000ms after each block and a longer break of 30 seconds after every three blocks. The image duration was 800ms with a randomly selected inter-stimulus interval of either 500, 750 or 1500ms. Items within each block were presented sequentially in a random order with the constraint that two crime items could not occur consecutively. The targets were randomly presented within each block and did not change irrespective of what crime items were selected by participants. Target items were not analysed as they were only used to ensure participant engagement with the stimuli. The data from participants with error rates (i.e. pressing “Yes” to a crime item) above 50% were removed from further analysis as it is unlikely that they were following the task instructions. Responses faster than 200ms or slower than 800ms were removed, as recommended by Verschuere and colleagues (2015). Incorrect responses were also removed from the RT analysis.

### **Procedure**

Participants completed the experiment in a computer lab with all fifteen pairs seated at fifteen computers completing the task as a pair (on the same monitor and with the same keyboard). Participants were provided with an overview of the study procedure, given the opportunity to ask questions and then provided consent and demographic information. Participants were informed of their right to withdraw at any point without penalty or reason. Participants were then asked to imagine that they were both “*undercover spies from Warwick University and have infiltrated New York University to steal their latest research. New York University Security suspects a mole and are therefore requiring all staff to sit a ‘lie detection test.’ Their ‘lie detection test’ assumes that spies will be slower to recognise and make more mistakes when they respond to images of New York University. They are also hoping to catch spies that accidentally respond “Yes” to images of Warwick University who*

*they believe are the prime suspects.” Participant pairs were told that both their lie detection performances would be considered together “Both of you must pass the test to remain undetected meaning your partners performance affects your score and vice versa!”.*

The participants were then given five images of ‘New York University’ and told to memorise these to help them beat the lie detection test. Participants were then told that *“during the ‘Lie Detection Test’ you will be shown a series of items of scenes. Many of these items will be unfamiliar to you except the ones relating to Warwick University (which you must keep secret) and the scenes of New York University which you have just memorised. Each image will appear for around 1 second with less than a second gap between them. Using the keyboard, please respond to these images as fast as you can making as few errors as possible! The question to consider for each image is ‘Do you recognise this scene?’”* One participant in each pair was instructed to press the LEFT KEY for “Yes” responses, i.e. New York University Images (targets), and the RIGHT KEY for “No” i.e. University of Warwick (crime items) and any other random images (control items). The additional participant in each pair used the Z KEY for “Yes” responses, i.e. New York University Images and the C KEY for “No” i.e. University of Warwick and other random images. Participants were given the opportunity to ask any questions before completing a practice test consisting of two blocks of trials (60 images). During the practice stage only, if the response was incorrect e.g., “Yes” response to a crime item, the words “Wrong” were displayed until the start of the next trial. If a response time exceeded the deadline of 800ms the words “Too Slow” were displayed until the start of the next trial. Participants were aware that this information would

not be provided following the practice stage. Following the practice test, participants completed the main test followed by debriefing.

## Results

Three participants were removed from the analysis due to their error rates being above 50% (94%, 85% and 86%). Including target items, trials that exceeded the response deadline of 800 ms (0.72%), were faster than 200ms (0.21%) and incorrect trials (5.0%) were removed from the analysis – note, incorrect responses are used for the error analysis.

### Reaction Times

Mean correct RTs were calculated for crime and control items for each participant with overall means shown in [Figure 3.14](#). A paired t-test on Item Type revealed that mean correct RTs were significantly slower for crime items compared to the control items,  $t(26) = 6.06, p < .001, d = .753, (MD = 25.9)$ .

### Error Rates

Error rates on crime and control trials were low overall ( $M = 2.2\%, SD = 2.4$  and  $M = 3.4\%, SD = 3.6$  for control and crime items respectively) and there were more errors to crime items,  $t(26) = 2.16, p = .040, d = .396, (MD = 1.21)$  ([Figure 3.15](#)).



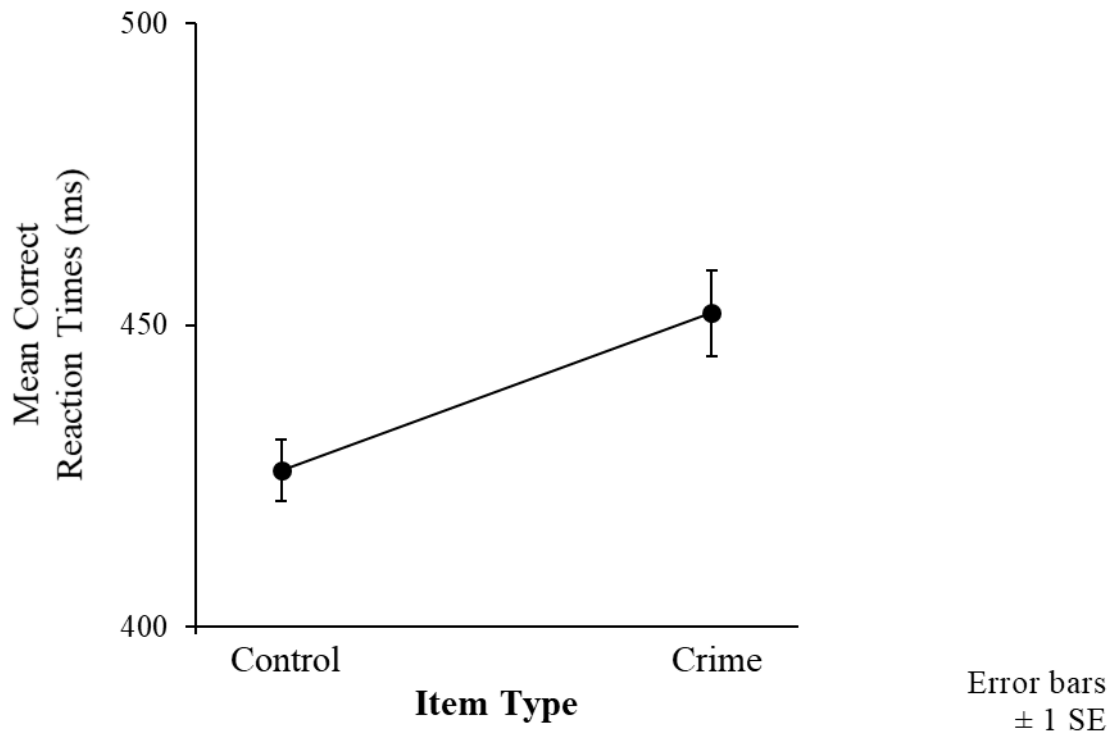


Figure 3.14. Mean correct RTs as a function of Item Type.

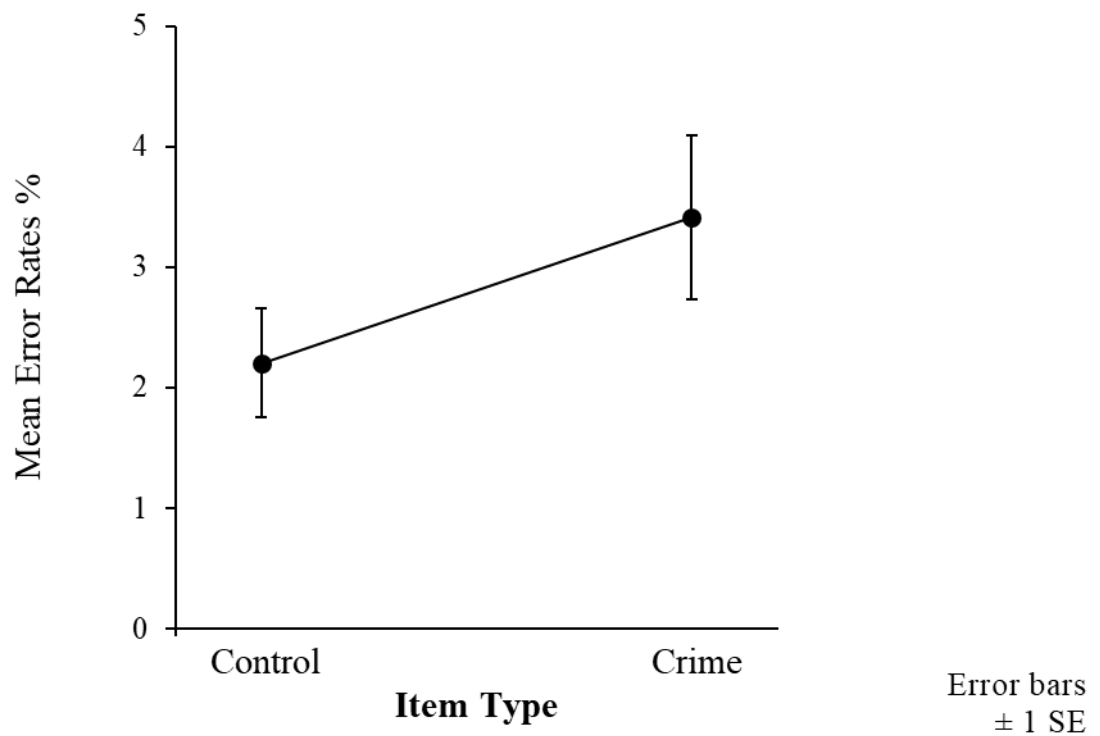


Figure 3.15. Experiment 4 - Mean error rates as a function of Item Type.

### Signal Detection Analysis

To assess the efficiency of deception detection, a signal detection analysis was conducted (Figure 3.16) using within-subjects standardised scores (z-scores) for each participant's RTs (Ben-Shakhar, 1985). Data for innocent participants was simulated by drawing random RTs from a standard normal distribution. This is conducted for each trial with one trial in five then randomly chosen to represent the simulated crime item. The resulting group-based RT-CIT had an  $AUC = .881$ , indicating an excellent diagnostic test with a large Guilty-Innocent effect size  $d = 1.22$ .

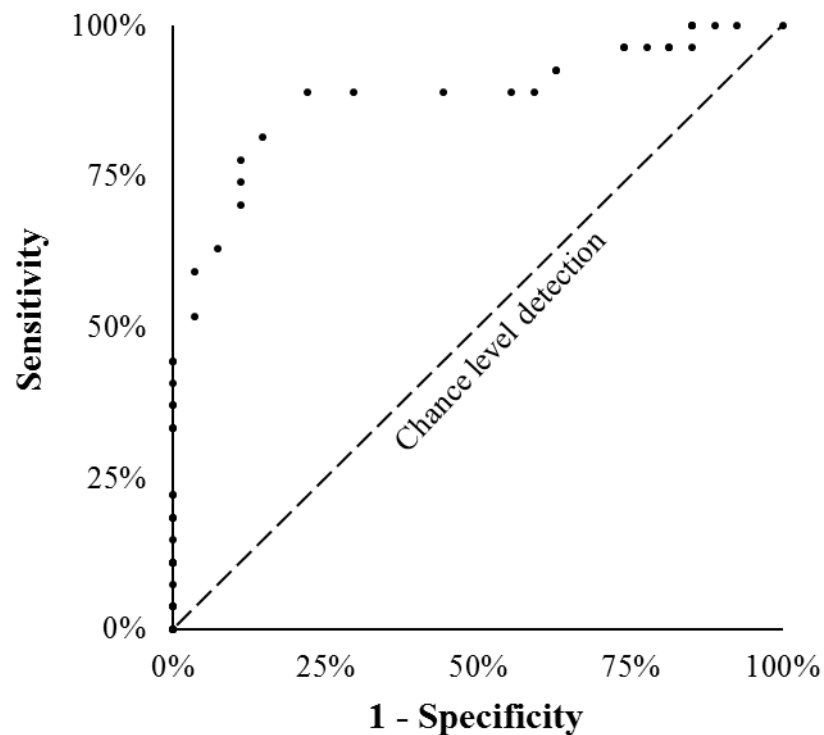


Figure 3.16. Experiment 4 - Signal detection curve (ROC) showing the detection sensitivity and specificity between guilty and simulated innocent participants

### Discussion

A recent meta-analysis demonstrated that the RT-CIT is an effective method for revealing suspects' crime recognition when suspects are tested alone ([Suchotzki et al., 2017](#)). In this experiment, we tested whether a group RT-CIT could be just as effective for revealing concealed information shared by pairs of crime suspects. There were reasons to believe it may not be as effective, but this had not been demonstrated previously. To check this, participant pairs underwent a scene-based RT-CIT in pairs. In Chapter 2 (Experiment 2), scene images were found to result in a similar RT-CIT effect compared to objects. All crime items were scenes of the participants' University Campus and therefore could be considered as autobiographic details. In the current experiment, participant pairs were instructed to jointly conceal recognition of these scenes. The results showed that a medium to large RT-CIT effect was present for participants tested in pairs which, when compared to simulated innocent participants, led to an excellent diagnosticity ( $AUC = .881$ ). Additionally, error rates were larger for crime items compared to controls. These findings suggest that a group RT-CIT can be used to reveal deception, suggesting that any potential distraction from participants' partners do not negate the RT-CIT effect. However, it is not yet clear whether the RT-CIT effect differs between those tested together and separately and therefore this should be tested.

### **Experiment 5: Paired vs. Individual RT-CIT**

In the previous experiment, the RT-CIT was found for participants undergoing a paired RT-CIT suggesting that group testing can reveal deception. However, in Experiment 4, no comparison was made between participants tested together and separately. In the current experiment, a within subject design was used in which participants underwent two scene-based RT-CITs (the same one used in Experiment 4) both together and separately with the order counterbalanced. In the event of an order effect, the 2<sup>nd</sup> condition completed by participants would be discarded for an additional planned between-subjects analysis. The results from this experiment would determine whether a paired RT-CIT differed from the standard individual RT-CIT.

#### **Method**

##### **Participants**

Forty participants (4 women), aged between 18-25 years (*Mean* = 21.2, *SD* = 1.3) were recruited, as pairs, through a convenience sample of students at the University of Warwick. Participants received no credit for taking part in the 40-minute testing session but did have the opportunity to receive their 'lie detection score' with the chance to win a £25 Amazon voucher each if they, as paired, obtained the lowest score. Participants were equally split and allocated in an alternating fashion between the order conditions.

##### **Materials**

The materials and CIT were the same as Experiment 4. To summarise: five scenes of University Campus were used as crime items equating to 450 trials; five other images of 'New York University' were used as target items present only to

ensure engagement with the task – target trials were not analysed; responses faster than 200ms and slower than 800ms were removed along with incorrect responses.

### **Procedure**

The procedure and instructions were the same as Experiment 4, with one exception. All participants were tested both together and separately sequentially with this order counterbalanced. Therefore, the study had a 2 (Testing: Together vs. Separate) x 2 (Order: Together 1<sup>st</sup>, Separate 1<sup>st</sup>) x 2 (Item: Control vs. Crime) three-way mixed-design with Order as the between-subject factor and RTs and error rates as the dependent variables. In other words, participants took the same RT-CIT twice (except stimuli were randomized in both separately), one alone and one with their partner.

### **Results**

The main finding was that the RT and error rate CIT effect was present although the Order factor interacted with Testing. After removing the order factor by only considering participants' first test only, the RT-CIT effect was smaller for those tested together.

No data were removed from the analysis due to participant error rates being over 50%. Including target items, trials that exceeded the response deadline (0.66%), were faster than 200ms (0.55%) and incorrect trials (1.64%) were removed from the analysis. Note, incorrect responses are used for the error analysis.

### **Reaction Times**

Mean correct RTs were analyzed using a 2 (Testing: Together vs. Separate) x 2 (Order: Together 1<sup>st</sup>, Separate 1<sup>st</sup>) x 2 (Item: Control vs. Crime) three-way mixed-design with Order as the between-subject factor ([Figure 3.17](#)). This revealed a significant main effect of: Item,  $F(1, 38) = 93.2, p < .001, MSE = 42305, \eta_p^2 = .710$ ,

overall RTs were slower to crime compared to control items; Testing,  $F(1, 38) = 58.9$ ,  $p < .001$ ,  $MSE = 78102$ ,  $\eta_p^2 = .608$ , overall RTs were slower when participants were tested together; and Order,  $F(1, 38) = 6.83$ ,  $p = .013$ ,  $MSE = 14829$ ,  $\eta_p^2 = .152$ , where overall RTs were faster when participants were tested together initially. There was a significant two-way interaction between Item and Order,  $F(1, 38) = 11.6$ ,  $p = .002$ ,  $MSE = 5251$ ,  $\eta_p^2 = .233$ , the RT-CIT effect (crime minus control RTs) was larger when participants were tested together first,  $t(38) = 2.71$ ,  $p = .010$ ,  $d = .793$  ( $MD = 19.1$ ). There were no significant two-way interactions between Item and Testing,  $F(1, 38) = .684$ ,  $p = .414$ ,  $MSE = 143$ ,  $\eta^2 = .018$ ; or Order and Testing,  $F(1, 38) = .946$ ,  $p = .337$ ,  $MSE = 1254$ ,  $\eta_p^2 = .024$ . There was no significant three-way interaction between Item, Order and Testing,  $F(1, 38) = 2.43$ ,  $p = .127$ ,  $MSE = 508$ ,  $\eta_p^2 = .060$ .

Given the Order x Item interaction, an analysis of only the 1<sup>st</sup> RT-CIT seen by each participant was conducted, thereby making it a between-subject design. Mean correct RTs were analyzed using a 2 (Testing: Together vs. Separate) x 2 (Item: Control vs. Crime) two-way mixed-design with Testing as the between-subject factor. This revealed a significant main effect of: Item,  $F(1, 38) = 50.0$ ,  $p < .001$ ,  $MSE = 16769$ ,  $\eta_p^2 = .568$ , overall RTs were slower to crime items compared to controls; and Testing,  $F(1, 38) = 5.71$ ,  $p = .022$ ,  $MSE = 12434$ ,  $\eta_p^2 = .131$ , overall RTs were slower when participants were tested together. There was a significant two-way interaction between Item and Testing,  $F(1, 38) = 5.45$ ,  $p = .025$ ,  $MSE = 1831$ ,  $\eta_p^2 = .125$ ; the RT-CIT effect was larger when participants were tested separately.

### Error Rates

Error rates on crime and control trials were low overall ( $M = 1.62\%$ ,  $SD = 0.28$  and  $M = 1.07\%$ ,  $SD = 0.19$  for crime and control respectively). Mean error rates were analyzed in the same manner as RTs above (Figure 3.18). This revealed a

significant main effect of Item,  $F(1, 38) = 10.6, p = .002, MSE = 11.7, \eta_p^2 = .219$ , overall errors rates were larger to crime items compared to controls. There was no significant main effect of Testing,  $F(1, 38) = 2.91, p = .096, MSE = 7.27, \eta_p^2 = .071$ ; or Order,  $F(1, 38) = 1.34, p = .254, MSE = 5.05, \eta_p^2 = .034$ . There was no significant two-way interactions between Item and Order,  $F(1, 38) = .092, p = .763, MSE = .101, \eta_p^2 = .002$ ; Item and Testing,  $F(1, 38) = 1.92, p = .174, MSE = 1.95, \eta_p^2 = .048$ ; or Order and Testing,  $F(1, 38) = 1.20, p = .281, MSE = 2.99, \eta_p^2 = .030$ . The three-way interaction was also non-significant,  $F(1, 38) = .169, p = .683, MSE = .172, \eta_p^2 = .004$ .

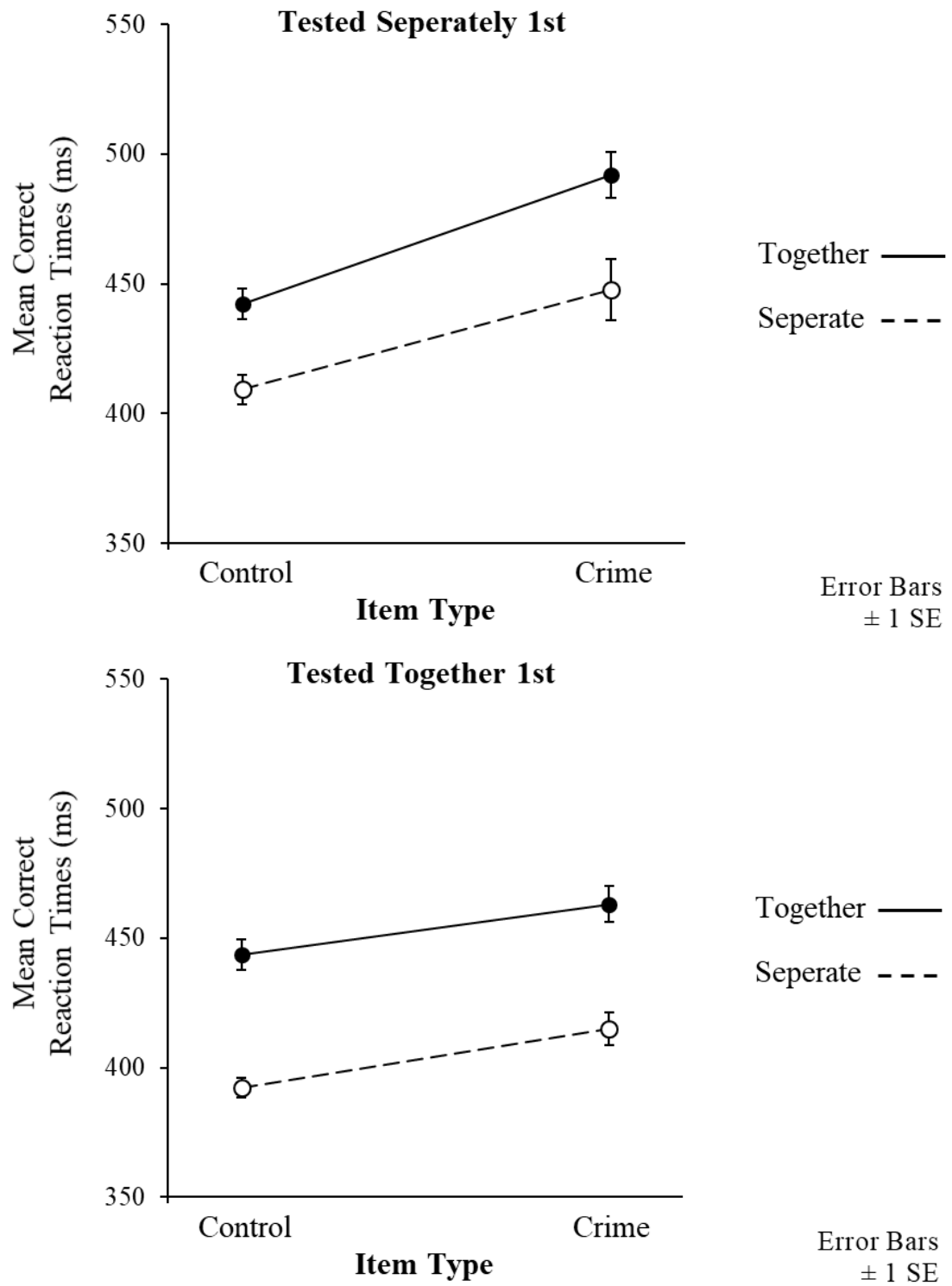


Figure 3.17. Experiment 5 - Mean correct RTs as a function of Item Type, Testing and Order.



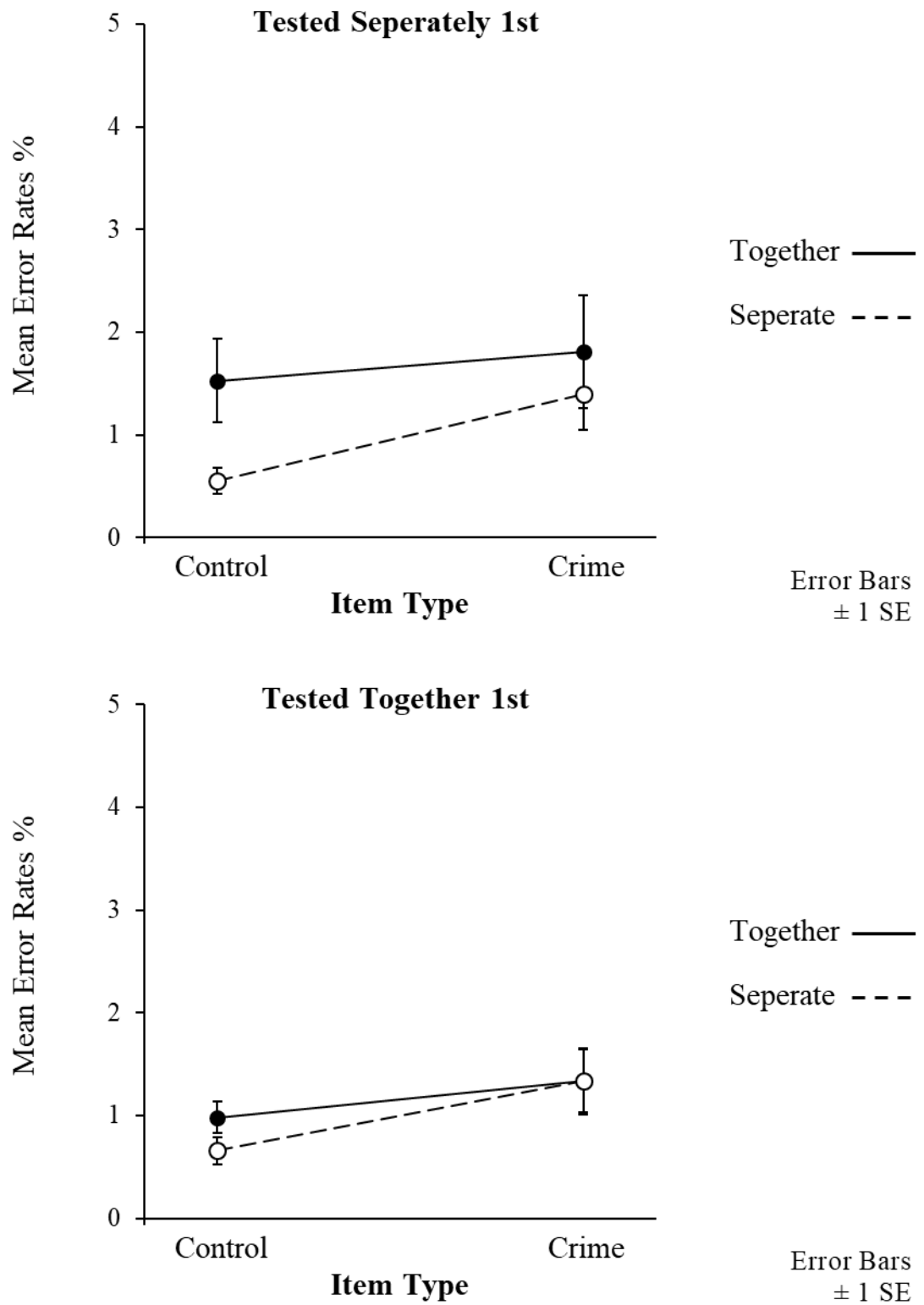


Figure 3.18. Experiment 5 - Mean error rates as a function of Item Type, Testing and Order.

### Signal Detection Analysis

Following on from Experiment 4, a signal detection analysis was conducted for each Order group using only their first RT-CIT (Figure 3.19). For participants who completed the Separate RT-CIT first, the  $AUC = .976$  indicated an outstanding diagnostic test with a large Guilty-Innocent difference effect size  $d = 1.57$ . For participants who completed the Together RT-CIT first, the  $AUC = .856$ , indicating an excellent diagnostic test with a large Guilty-Innocent difference effect size  $d = 1.18$ . Detection was best when participants were tested separately,  $AUC\ diff = .12$ ,  $SE = .06$ ,  $z = 1.81$ ,  $p = .035$ .

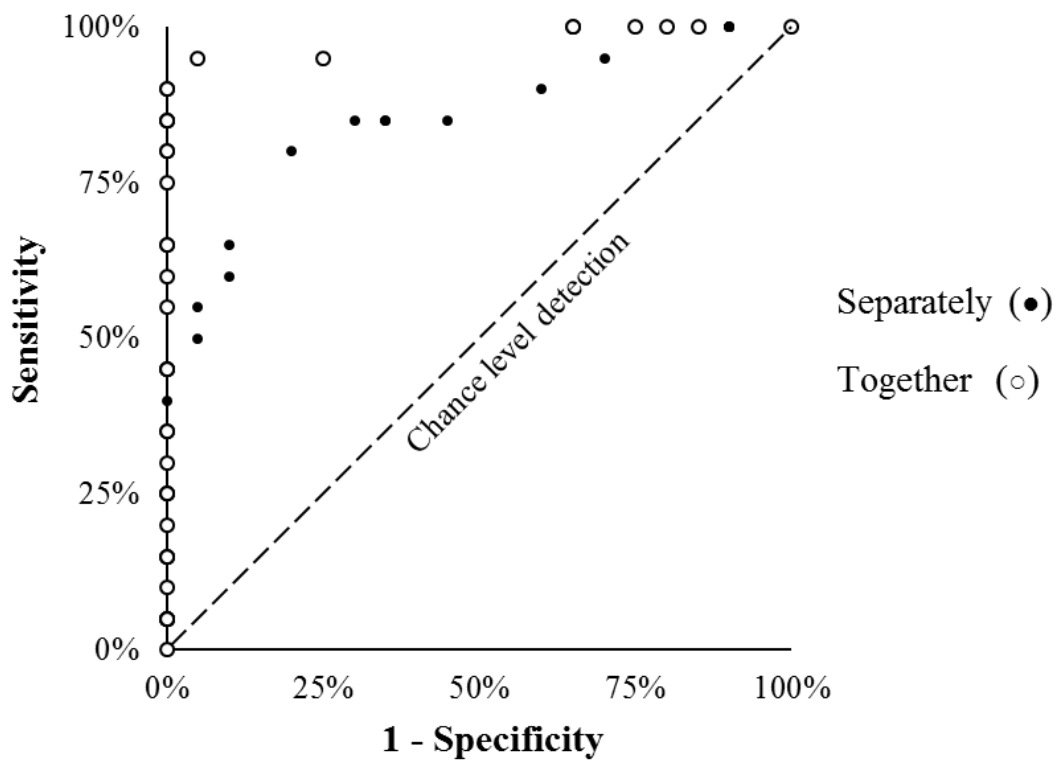


Figure 3.19. Experiment 5 - Signal detection curve (ROC) showing the detection sensitivity and specificity between guilty and simulated innocent participants for both when participants were tested together and separately

### **Discussion**

This experiment investigated whether the RT-CIT differed when participants were tested together compared to separately. The initial concern raised about conducting a group RT-CIT was that it may result in a reduction of participant stimulus processing due to distractions caused by the other partner undergoing testing. In Experiment 4 however, we found a medium to large RT-CIT effect indicating that the RT-CIT effect was not negated. This experiment went further by comparing this to a control condition i.e. a condition where participants underwent the RT-CIT alone. The same scene-based RT-CIT scenario, procedure and tests was the same as that used in Experiment 4 except participants took two RT-CIT tests consecutively. The order of whether they took the RT-CIT as a pair first or second was counterbalanced.

Interestingly, the order factor interacted with the item type where RT-CIT effect was larger when participants were tested together first. Due to this order effect, a planned analysis of only the first RT-CIT taken by participants was conducted. This showed that the RT-CIT was larger when participants were tested separately indicating that the group RT-CIT was inferior. Consequently, detection of concealed information was greater when participants were tested separately.

These initial findings indicate that, unlike the physiological CIT, the RT-CIT should be administered to suspect pairs individually for knowledge that is shared. To confirm this finding and re-introduce the knowledge factor (Shared, Exclusive and Unknown) tested in Experiments 2 and 3 of this chapter, a final experiment was ran.

### **Experiment 6: Shared Knowledge and Paired RT-CIT**

In Experiment 5, the RT-CIT was found for both participants tested separately and together, however appeared smaller in the later condition. In Experiments 2 and 3 of this chapter, the physiological-based CIT effect in group testing was affected by whether the participant pairs shared specific knowledge crime items or not. Having established that the RT-CIT is still present in paired RT-CIT, the current experiment was conducted as a replication of Experiment 2 (and 3) to determine whether there is any impact of knowing that your partner also recognizes the crime item (Shared knowledge) on the RT-CIT effect.

In the introduction section of this chapter, Encoding Specificity Theory was presented, which predicts that information both encoded and retrieved together would result in a larger recognition effect compared to when there is a mismatch in encoding. This prediction was supported by the findings in Experiments 2 and 3 with the physiology CIT when measuring SCR. However, whether or not the same findings would be found in the RT-CIT is unclear. The SCR measure in the CIT is taken to represent that a magnitude of recognition has occurred. Therefore, we might expect theories such as Encoding Specificity to affect this measure. However, like heart rate, which was not impacted by group testing or shared knowledge, the RT-CIT effect does not appear to be a recognition response. Rather, the RT-CIT effect is believed to relate to the response conflict experienced by participants deceptively responding to stimuli presented rapidly. Therefore, other cognitive processes such as task co-representation ([Barber, Harris, & Rajaram, 2015](#)) may be more important when participants are tested together with shared and non-shared information in the RT-CIT.

Therefore, as in Experiment 2, this experiment tested whether the RT-CIT effect differs between different knowledge held by suspect pairs and whether taking the CIT together or separately impacts this. The same two mock crime videos from Experiment 2 were used in which the thieves either encounter crime information together (*Shared Knowledge*) or individually (*Exclusive Knowledge*) and were not exposed to their partners' exclusive knowledge (*Unknown Knowledge*). Participant pairs then underwent a RT-CIT either *Together* or *Separately*.

## Method

### Participants

In line with Experiment 2, sixty-four participants (31 women and 7 not disclosing), aged between 18 - 51 years ( $Mean = 22.6$ ,  $SD = 7.3$ ) were recruited as pairs through a convenience sample of students and staff at the University of Warwick. Participants received no credit for taking part in the 40-minute testing session but did have the opportunity to receive their 'lie detection score' with the chance to win a £25 Amazon voucher each if they, as a pair, obtained the lowest score. Participants were equally split and allocated in an alternating fashion between either the paired or the separate condition until the sample size of Testing condition reached thirty-two.

### Procedure

The mock crime video stimuli, CIT stimuli, procedure, instructions and additional measures questionnaire, were the same as those used in Experiment 2. The exception was that an RT-CIT was used instead of a physiological CIT. Consequently, the CIT now contained 54 images (nine crime items each with four matched items and one target item) which was repeated 15 times. All other RT-CIT parameters were the same as in Experiment 4 and 5. In outline, participant pairs

watched a mock crime video where they either both encoded the same crime knowledge (*Shared*), encoded individual crime knowledge (*Exclusive*) and were not exposed to their partners' exclusive knowledge (making it *Unknown*). Participant partners then took a RT-CIT either at the same computer at the same time (*Together*) or one at a time (*Separate*). The experiment therefore had a 2 (Tested: Together vs. Separate) x 3 (Knowledge Type: Unknown vs. Exclusive vs. Shared) mixed-design with Knowledge as the within-subject factor and RT-CIT effect and Error CIT effect (crime minus control) as dependent variables.

### Results

The main finding was that there was no effect of being tested together or separately however, ignoring the testing factor, shared knowledge items resulted in the greatest RT-CIT effect, followed by exclusive items with unknown items as the smallest. Note that the RT-CIT effect for exclusively known stimuli was minimal for both participants tested Together ( $M = -2.9$ ,  $SD = 19.5$ ) and Separately ( $M = 6.12$ ,  $SD = 25.7$ ).

#### Reaction Times

No data were removed from this analysis due to participant error rates being over 50%. Including target items, trials that exceeded the response deadline (0.76%), were faster than 200ms (0.32%) and incorrect trials (7.35%) were removed from the analysis – note, incorrect responses are used for the error analysis.

Normalized, mean correct RT-CIT effects were analyzed using a 2 (Tested: Together vs. Separate) x 3 (Knowledge Type: Unknown vs. Exclusive vs. Shared) two-way mixed ANOVA with Knowledge as the within-subject factor (Figure 3.20). This revealed a significant main effect of Knowledge Type,  $F(2, 124) = 42.0$ ,  $p < .001$ ,  $MSE = 18352$ ,  $\eta_p^2 = .404$ , However, neither the main effect of Testing,  $F(1,$

62) = 2.36,  $p = .129$ ,  $MSE = 1065$ ,  $\eta_p^2 = .037$ , nor the Knowledge x Testing interaction,  $F(1, 124) = .522$ ,  $MSE = 228$ ,  $p = .595$ ,  $\eta_p^2 = .008$ , approached significance. Ignoring the Testing condition, post hoc pairwise comparisons revealed that: RT-CIT effects were larger to exclusively known items compared to unknown items,  $t(63) = 2.93$ ,  $p = .005$ ,  $d = .501$ , ( $MD = 10.6$ ); RT-CIT effects were larger to shared items compared to unknown items,  $t(63) = 8.78$ ,  $p < .001$ ,  $d = 1.28$ , ( $MD = 33.2$ ); and RT-CIT effects were larger to shared items compared to exclusively known items,  $t(63) = 6.2$ ,  $p < .001$ ,  $d = .889$ , ( $MD = 22.5$ ). Additionally it was found that the expected RT-CIT effect (crime vs. control items), although present for shared items,  $t(63) = 8.86$ ,  $p < .001$ ,  $d = .434$ , ( $MD = 24.1$ ), was not present for exclusively known items,  $t(63) = .556$ ,  $p = .556$ ,  $d = .031$ , ( $MD = 1.61$ ).

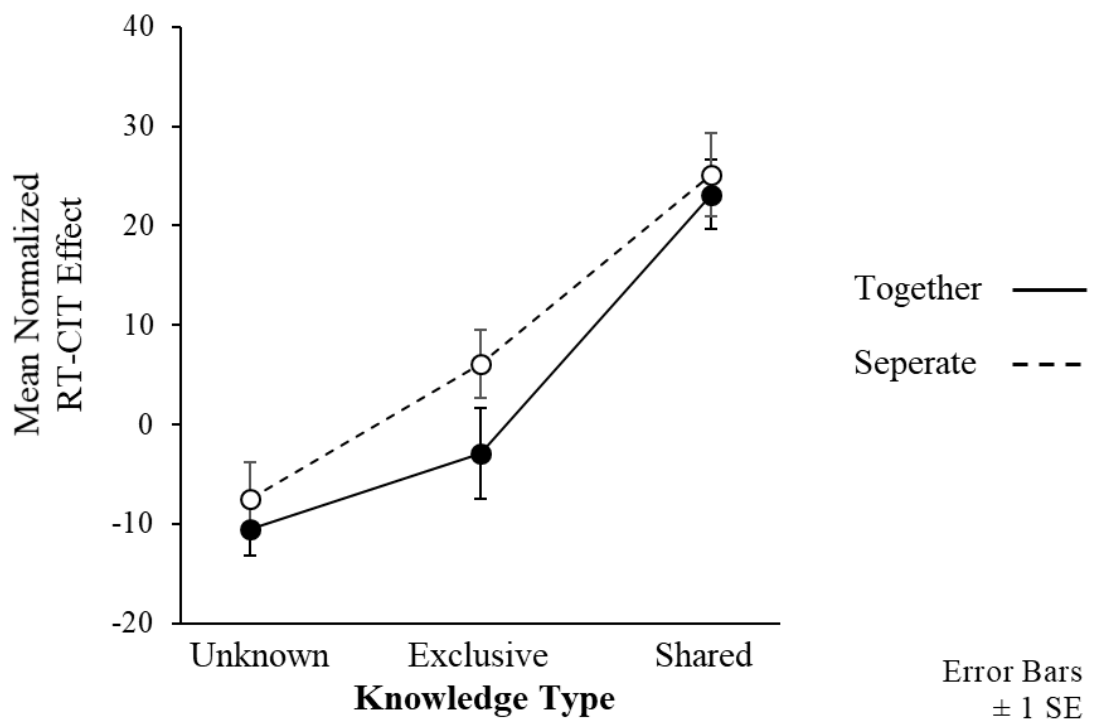


Figure 3.20. Experiment 6 - Mean correct RT-CIT effect as a function of Item Type and Condition.

### Error Analysis

Error rates on probe and irrelevant item trials were low overall ( $M = 2.81\%$ ,  $SD = 4.75$  and  $M = 1.25\%$ ,  $SD = 3.17$  for probe and irrelevant respectively). Mean error CIT effects were analyzed in the same way as for the RTs (Figure 3.21). This revealed a significant main effect of Knowledge Type,  $F(2, 124) = 11.3$ ,  $p < .001$ ,  $MSE = 200$ ,  $\eta_p^2 = .154$ . However, neither the main effect of Testing,  $F(1, 62) = 1.40$ ,  $p = .242$ ,  $MSE = 26.5$ ,  $\eta_p^2 = .022$ , nor the interaction between Knowledge and Testing,  $F(1, 124) = .360$ ,  $MSE = 6.38$ ,  $p = .699$ ,  $\eta_p^2 = .006$ , approached significance. Ignoring Testing, post hoc pairwise comparisons revealed that: the error CIT effect was larger for exclusively known items compared to unknown items,  $t(63) = 3.8$ ,  $p < .001$ ,  $d = .579$ , ( $MD = 1.50$ ); the error CIT effect was larger for shared items compared to unknown items,  $t(63) = 4.23$ ,  $p < .001$ ,  $d = .704$ , ( $MD = 3.52$ ); the error CIT effect was larger to shared items compared to exclusively known items,  $t(63) = 2.27$ ,  $p = .027$ ,  $d = .391$ , ( $MD = 2.03$ ). Additionally it was found that the expected error CIT effect (crime vs. control items), was present for both shared items,  $t(63) = 4.21$ ,  $p < .001$ ,  $d = .710$ , ( $MD = 3.41$ ), and exclusively known items,  $t(63) = 3.48$ ,  $p = .001$ ,  $d = .562$ , ( $MD = 1.38$ ).



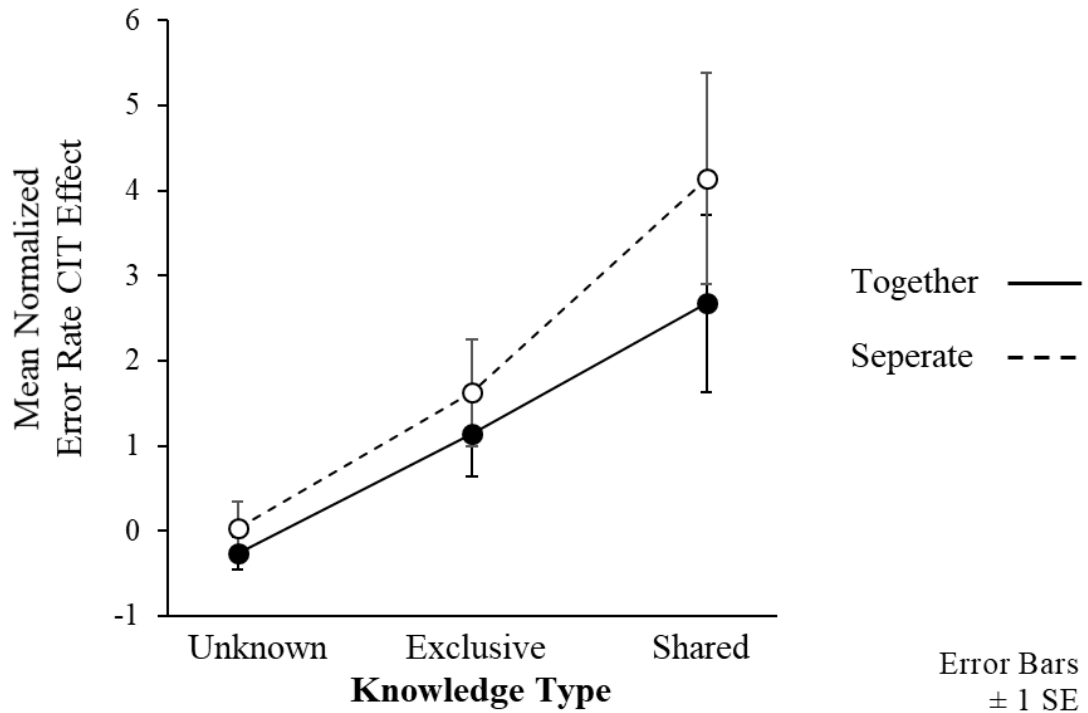


Figure 3.21. Experiment 6 - Mean error CIT effect as a function of Item Type and Condition.

### Post CIT Questionnaire

As with Experiments 2 and 3, there were no differences between those tested together and separately for the additional factors measured (motivation, stress and countermeasure use) in this experiment. Participants correctly recalled 95.1% of crime items with nineteen participants forgetting at least one of the six crime items (one forgot five, two forgot two and sixteen forgot one). Participants found the mock crime video immersive, Mean = 4.3,  $SD = 1.2$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>). Overall participants' self-reported motivation was moderate with Mean = 5.0,  $SD = 0.9$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>), with no difference between Testing conditions,  $t(62) = .306$ ,  $p = .760$ , ( $MD = .094$ ). Overall, participant's self-reported stress during the CIT was moderate with Mean = 3.7,  $SD = 1.3$  (range = 1<sub>no stress</sub> to 6<sub>highly stressed</sub>), with no difference between Testing conditions,  $t(62) = 1.11$ ,  $p = .272$ , ( $MD = .406$ ). Participants rated the mock crime videos as immersive with Mean = 4.5,  $SD = .95$

(range = 1<sub>not immersive</sub> to 6<sub>highly immersive</sub>). Eleven participants (17%), reported using some form of countermeasure to fool the test: four reported to randomly change their response time; four tried to respond at the same speed to all items; one tried to respond faster to crime item; one made intentional mistakes; and one tried to slow all responses to all item.

### **Order Factor Check**

Participants tested Separately were either tested before or after their partner and this was counterbalanced. To check for order effects, mean RT-CIT and error CIT effects were analyzed using a 2 (Order: First vs. Second) x 3 (Knowledge: Unknown vs. Exclusive vs. Shared) mixed-ANOVA with Knowledge as the within-subjects factor. There was no main effect of Order for the RT-CIT effect,  $F(1, 30) = .498, p = .486, MSE = .238, \eta_p^2 = .016$ , or Error CIT effect,  $F(1, 30) = .034, p = .855, MSE = .526, \eta_p^2 = .001$ . There was also no interaction between Order and Knowledge, the RT-CIT effect,  $F(2, 60) = .696, p = .502, MSE = .285, \eta_p^2 = .023$ , and Error CIT effect,  $F(2, 60) = .038, p = .963, MSE = .561, \eta_p^2 = .001$ . This again suggested that the order that participants were tested separately had no impact on the findings.

### **Signal Detection Analysis**

Following Experiment 5, a signal detection analysis was conducted revealing that the  $AUC = .793$ , indicating a good diagnostic test with a large Guilty-Innocent difference effect size  $d = .984$ . ([Figure 3.22](#)).

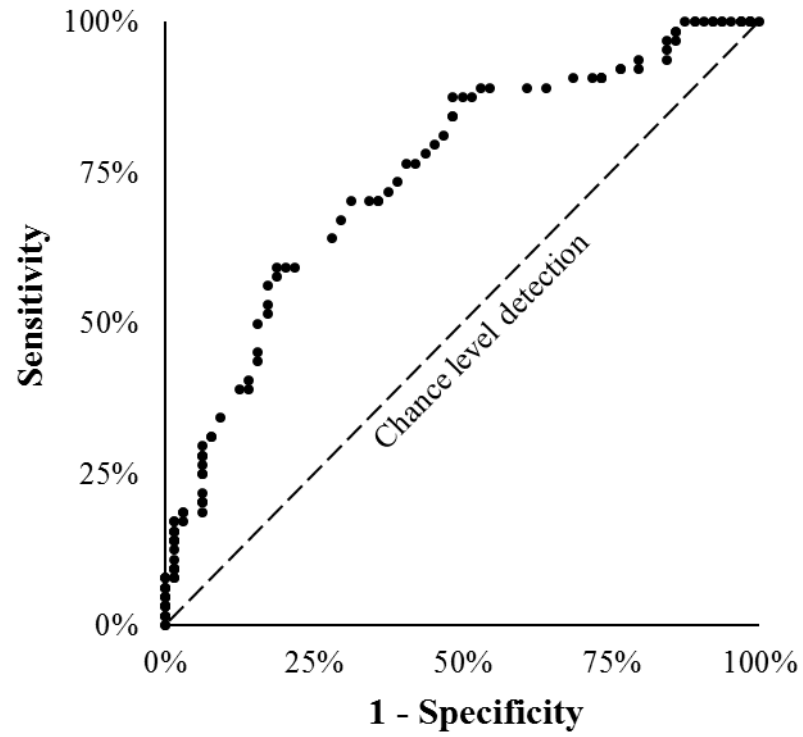


Figure 3.22. Experiment 6 - Signal detection curve (ROC) showing the detection sensitivity and specificity between guilty and simulated innocent participants

### Discussion (Part 2.)

The group CIT has been proposed as a method for extracting key information from criminal groups where one or more share this information. In Experiments 4 and 5, it was established that the RT-CIT remains effective for testing pairs of suspects that have shared crime knowledge. Following on from this, the current experiment tested whether the RT-CIT effect differs between different knowledge held by suspect pairs and whether taking the CIT together or separately impacts this - the same mock crime stimuli were used.

The results showed no effect of being tested together or separately for either RTs or error rates. However, when collapsed over testing groups (together and separate), all pairwise comparisons between different knowledge types (Unknown, Exclusive and Shared) were significant for both the RT-CIT effect and the error rate CIT effect. This meant that the CIT effect was larger for shared information compared to exclusive which was in turn larger than unknown information. This suggests that something is uniquely affecting the shared items regardless of the testing condition. However, note that the RT-CIT effect for exclusively known condition was not present ( $d = .031$ ) and small for shared items ( $d = .434$ ). This could be due to the number of crime items tested - three for each knowledge type. The number of crime items has been shown to reduce the CIT effect ([Meijer et al., 2014](#)) and may therefore explain why the overall RT-CIT effect was small, or in the case of the exclusive items, negligible. Finally, there was no difference between the self-reported motivation, stress and countermeasure use across both testing conditions, and no difference between participant partners that underwent the CIT first or second in the separate CIT testing condition, suggesting that none of these factors can account for these findings.

This is the first experiment to test the effects of group vs individual CIT testing and its impact on the RT-CIT effect for shared information. Our findings suggest that deception, as measured using an RT-CIT, can be better detected when pairs of suspects respond to shared knowledge items. When considering the reduced deception diagnosticity found in this experiment, using the RT-CIT to reveal deception may not be optimal when participants collaborate on a crime. This suggests that a group based searching CIT using RTs would not be as effective as using physiological measures (e.g. [Bradley & Barefoot, 2010](#); [Breska, Ben-Shakhar, & Gronau, 2012](#); [Breska et al., 2014](#); [Elaad, 2016](#); [Meijer et al., 2010](#); and [Meijer et al., 2013](#)). Furthermore, the findings from group-based RT-CIT may provide theoretical insights into the processes that modulate the RT-CIT or interfere with response inhibition. This requires further study.

### Chapter Summary

Often the most damaging criminal activity is that planned and conducted by organized groups. To help the fight against such crime, the group CIT has been proposed as a method for extracting critical information from criminal groups (e.g. [Elaad, 2016](#)). The efficiency of group CITs have been tested using physiological measures however so far no one has compared the effects of testing suspects in groups versus alone which is the more typical CIT approach. In this chapter, the effects of testing participant pairs together in both the physiological and RT based CITs is explored. In Part 1, using the physiological CIT, pairs watched a collaborative mock crime video in which they encoded either shared or non-shared crime information before undergoing a CIT either together or separately (Experiments 2 and 3). Across both, the SCR CIT effect was larger when both participant partners sat next to each other in the CIT recognized the same crime details. Combining data from Experiment 2 and 3 revealed an additional effect. The SCR CIT effect was reduced when participants, without their partner present, saw crime details known by both them and their partner.

Encoding Specificity ([Tulving & Thomson, 1973](#)) can account for these findings as groups of people who encode and retrieve information alone benefit from both context-dependent learning and transfer-appropriate processing whereas groups encoding individually but retrieving collaboratively suffer due to a mismatch in encoding ([Barber, Rajaram & Aron, 2010](#)) – this is what we observed with the SCR data. For the heart rate data however, this was not the case as no effect of testing or knowledge was found. Response fractionation theory suggests that whilst SCR relates to recognition via orienting, heart rate change is better accounted for by arousal inhibition experienced when responding deceptively and suppressing

recognition of items (Verschuere, Meijer, & De Clercq, 2011; klein Selle et al., 2016; klein Selle et al., 2017). In sum, for the physiological CIT at least, these initial findings support the use of group-CIT methods for suspects but suggests group members are tested together.

The findings from Part 1 were followed up using the RT-CIT in Part 2. As the RT-CIT had not been conducted in pairs previously, Experiments 4 and 5 were conducted, using autobiographic scenes as crime details, to confirm that the RT-CIT effect wasn't negated in group testing. In Experiment 4 the RT-CIT effect was medium to large with an excellent diagnosticity ( $AUC = .881$ ) when compared to simulated innocent group. Experiment 5 directly compared the RT-CIT effect between participants who took the test together and then separately (and vice versa introducing an order factor). An order effect was found but following removal of this factor, detection of concealed information was found to be greater when participants were tested separately.

In Experiment 6, the crime knowledge held by both participant partners was manipulated in the same way as Experiment 2 i.e. partners no longer shared all crime information. However, unlike the findings with the physiological CIT, the results in Experiment 6, showed no interaction between testing and knowledge on either RTs or error rates. Collapsed over testing groups, the RT-CIT effect was larger for shared information compared to exclusive, which was in turn larger than unknown information. Although note that the RT-CIT was negligible for both unknown, and surprisingly, exclusive items. Overall this meant that there was no benefit of testing pairs together in the reaction time CIT.

The experiments in this chapter are the first to assess the potential benefits and costs of CIT testing suspects who have committed a joint crime together and what impact their knowledge of different crime information has.



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## CHAPTER 4

**What do you know?****Informed investigators may not increase false positives in  
concealed information tests****Abstract**

When administering forensic assessments of witness or suspect memory, research in social psychology cautions against using investigators who have knowledge about the crime due to the potential of biasing. In this study, investigator presence was experimentally manipulated in a Concealed Information Test (CIT). Innocent and guilty suspects watched first-person perspective videos, the latter a mock crime, before taking a CIT measuring skin conductance and heart rate. The CIT was administered by either a human investigator or a computer using a within-subjects (Experiment 1) and a between-subjects (Experiment 2) design. The investigator, knowledgeable of the crime but unaware of the suspect's guilt, asked each CIT question before presenting the stimuli as photographs. Guilty suspects showed larger skin conductance CIT effects when tested by an investigator, enhancing deception diagnosticity. However, no such investigator effect was found for innocent suspects suggesting knowledgeable investigators may not increase in false positives. Further work is recommended.

### Introduction

Given the choice of lying face-to-face or over the phone, most would typically choose the latter (DePaulo, Kashy, Kirkendol, Wyer, & Epstein, 1996) as it is more likely that the liar will be successful (Harrison, Hwalek, Raney and Fritz, 1978; Hancock, Woodworth, & Goorha, 2010). Performing any task, not just lying, is more difficult with an audience. An example is forgetting parts of a well-rehearsed presentation during delivery (Rosenberg, Rosenthal, & Rosnow, 1969). Indeed, decades of research (Bond & Titus, 1983) has shown that the mere presence of others, real, imagined or simply implied, can influence behavior and performance across a variety of tasks – this is known as *Social Facilitation* (Zajonc, 1965).

Unsurprisingly then, a criminal investigator, or detective, would prefer to interview a suspect in person rather than over the phone or through email/instant messaging. Deception detection research has shown that lying is less successful when performed face-to-face with an investigator (Hancock, Woodworth, & Goorha, 2010) even if the investigator is only present while a computer asked the questions (Harrison et al., 1978). One explanation for this is the *Motivational Impairment Effect* whereby suspects are more motivated to successfully deceive in the presence of an investigator but then are consequently more likely to fail (DePaulo et al., 2003). Despite the many benefits of having an investigator conduct an interview there is also a cost. Investigators usually only question a suspect when they have obtained evidence to suggest the suspect's involvement in the crime. This alone casts doubt on the suspect's innocence and consequently the investigator may start the interview with a particular hypothesis about the suspect's guilt. In this scenario, the investigator is likely to feel that the suspect's answers, truthful or not, are false resulting in an overall 'lie bias' (Vrij, 2008). Of course, it is not only pre-interview

evidence that may cause bias in a criminal investigator and any bias, even unintentional and unrealized, can change the investigator's behavior as well as the suspect's due to *Expectancy Effects*. 'Expectancy effects' refers to the phenomenon whereby one's beliefs or expectations about another person elicit behavioural confirmation of those initial beliefs. Many experiments have demonstrated this (Rosenthal, 2002; Richard, Bond Jr, & Stokes-Zoota, 2003) across a range of contexts with the effect sizes ranging from large (e.g. psychophysical measures) to small (e.g. for RT studies) (Rosenthal & Rubin, 1978). Various behaviors are important for the expectancy effect to occur (Harris & Rosenthal, 1985) with the primary one being unintentional cueing. Here an experimenter, teacher or criminal investigator can unintentionally change the behavior of a participant, student or suspect. A popular analogy for this is the case of Clever Hans, who could seemingly perform arithmetic – Clever Hans, however, was a horse. On closer examination it was demonstrated that the horse was simply responding to unintentional and involuntary cues from the person asking the questions (Sebeok & Rosenthal, 1981). In a police interview this type of influence can even result in false confessions (Kassin & Kiechel, 1996).

Consider an eyewitness line-up where a witness is shown several people. One person in the line-up may be the target, i.e. the perpetrator of the crime, with the others known not to have carried out the crime. The target can be absent, and all line-up members can be presented sequentially (preferred) or simultaneously. The witness must determine if the target is in the lineup. Some studies have shown that when the investigator administering the line-up is aware of who the target is, this changes the behaviour of the witness and can consequently increase false identifications (Perlini & Silvaggio, 2007; Phillips, McAuliff, Kovera, & Cutler, 1999; Douglass, Smith &

Fraser-Thill, 2005) and even halve eyewitness diagnosticity (Greathouse & Kovera, 2009). Similarly, other studies have shown that reducing contact between the administrators and witness mitigates this problem (Haw & Fisher, 2004). In sum, the investigator has influenced the witness's decision and memory for the actual perpetrator. Two mechanisms have been proposed to account for this: *Expectancy Effects* whereby knowledgeable investigators emit nonverbal cues that communicate the identity of the suspect to the witness, and *Confirmation Bias* whereby investigators ask witnesses specific questions that lead the witness to identify the suspect (Wells et al., 1998; Greathouse & Kovera, 2009). In light of this, many eyewitness scientists recommend the use of double-blind administrators who do not know who the target is in the line-up (Wells & Seelau, 1995; Rodriguez & Berry, 2012). That said, it should be noted that several studies have failed to find any expectancy effects in line-ups (Russano, Dickinson, Greathouse & Kovera, 2006).

Returning to detection deception techniques, one such method, the Concealed Information Test (CIT), does not typically use an investigator. In a CIT a suspect is presented with a number of questions relating to the crime such as "Question 1 of 5: Was this the weapon you used to kill Mr Smith?" followed by a number of plausible answers presented sequentially; "Bat, Knife, Pistol, Rope or Hammer". Guilty suspects who recognize the actual weapon, i.e. the crime item, respond differently compared to the control items. On contrast, innocent suspects, who have not been exposed to the crime details, respond similarly to all items. The guilty suspects' difference in responses to crime and control items is called the CIT effect, which results in larger skin conductance responses (SCRs) and a heart rate deceleration ( $\Delta HR$ ) and other parasympathetic measures (Verschuere, Ben-Shakhar, & Meijer, 2011). The CIT is predominantly administered via computer, often with the suspect

alone, due to concerns about the negative effects of an investigator (Meijer, Verschuere, & Ben-Shakhar, 2011, p. 300). Understandably, it is believed that an investigator, knowledgeable about the crime details and administering the CIT face-to-face, could unintentionally cue the actual crime detail to an initially unknowledgeable innocent suspect, resulting in a false positive CIT effect making an otherwise innocent suspect look like a guilty one.

So what benefit might there be to using an investigator in the CIT? The act of concealing information from another is inherently a social act, therefore having an investigator present during the CIT will likely increase a person's motivation, attention and emotion (Ambach, Assmann, Krieg, & Vaitl, 2012). Although the CIT effect is based mostly on cognitive theories, namely orienting, emotional and motivational factors have been shown to mediate it (Verschuere, Ben-Shakar, & Meijer, 2011). Studies have shown that the presence of another during a task can increase physiological arousal (Chapman, 1973; Hrycaiko & Hrycaiko, 1980; Mullen, Bryant, & Driskell, 1997), such as electrodermal responses (Mullen, Bryant, & Driskell, 1997) and, motivation, cognitive distraction and load (Jones & Gerard, 1967; Lambert et al., 2003). Importantly, such variables have been shown to impact the CIT: arousal (Peth, Vossel & Gamer, 2012); motivation (Ben-Shakhar & Elaad, 2003); cognitive load (Ambach, Stark & Vaitl, 2011; Visu-Petra, Varga, Miclea & Visu-Petra, 2013; Hu, Evans, Wu, Lee & Fu, 2013). Clearly, there is evidence to suggest the CIT could be affected by the presence of an investigator. However, this topic has received little attention and the effects of a real human investigator administering the CIT, compared to a computer have yet to be experimentally tested.

Social influence in the CIT was examined in one experiment by manipulating the presence of a 'virtual investigator' presented as a neutral face on a computer

monitor alongside the CIT images ([Ambach et al., 2012](#)). The resulting CIT effect for heart rate, respiration and peripheral vasodilation was larger when the virtual investigator was used ( $p < .05$ ,  $d = .48$ ) with no difference for the SCR. In another study, positive faces of a ‘virtual investigator’ placed on screen with each CIT trial, increased the RT-based CIT effect with the opposite effect occurring when a negative expression was presented ([Varga, Visu-Petra, Miclea, & Visu-Petra, 2015](#)). Although both studies indicate that the CIT may be susceptible to the presence of a virtual investigator, neither used a physical human to administer the CIT, thereby reducing any potential impact of expectancy effects and social presence. Two experiments used human investigators, blind to the suspects’ guilt, to administer the CIT but used pre-recorded questions to “minimize vocal inflections” to mitigate against any unintentional cueing ([Bradley & Warfield, 1984](#); and [Bradley & Rettinger, 1992](#)). No negative effects of using a human administrator were found. However, as that was not the aim of their experiment, as they were investigating the effects of information leakage, no comparison to a computer administered condition was conducted. Finally, one experiment using real police polygraphers, not blind to the suspects’ guilt, administered the CIT face-to-face and found that when the investigator knew about the crime items, the CIT effect decreased for the guilty suspects ([Elaad, 1997](#)). Again, they found no negative effect for innocent suspects but did for guilty suspects. However, no comparison to a computer administered group was conducted and therefore the effect of using an investigator was not established.

The current study directly tests the impact of using a human investigator, blind only to the suspects’ guilt, to administer a physiological CIT (based on SCR and  $\Delta HR$ ) face-to-face to both guilty and innocent suspects. Guilty suspects only, watched a mock crime video, thereby encoding eight crime details which the

investigator knew. In Experiment 1, within-subjects, the investigator administered half of the eight questions, the computer the remaining. In Experiment 2, between-subjects, the investigator or computer administered all eight questions. Finally, the results of Experiment 2 and the first block of Experiment 1 (which simulated a between-subject design) were combined for analysis. The investigator sat opposite the suspect asking each question followed by presenting photographs of the stimuli in a structured CIT fashion. The prediction based on previous literature described above is that the CIT effect will increase for both guilty and innocent suspects when the CIT is administered by an investigator compared to by a computer. All studies were approved by the departmental ethics committee at the authors' institution.



### Experiment 1: Investigator Influence

The CIT was administered by either a human investigator or a computer using a within-subjects design. *Guilty* participants watched a mock crime video where they were exposed to eight crime details; *Innocent* participants watched a non-crime video. Following this, all participants were administered a CIT with half of the stimuli presented as photographs by an *Investigator* and the remaining half presented via a computer program as images on a *Computer* monitor. Therefore, this study had a 2 (Suspect: Guilty vs. Innocent) x 2 (Presentation: Investigator vs. Computer) x 2 (Order: Investigator 1<sup>st</sup> vs. Investigator 2<sup>nd</sup>) mixed-design with Presentation as the within-subject factors. The dependent variables were SCR CIT effect and heart rate change ( $\Delta$ HR) CIT effect.

### Method

#### Participants

Ambach and colleagues (2012) found that the CIT effect was larger when a virtual investigator was presented alongside the CIT stimuli ( $d = .48$ ). A power analysis using G\*Power (Faul, Erdfelder, Lang, & Buchner, 2007), using this effect  $d = 0.48$ , and  $\alpha = 0.05$  for a single group, suggested a minimum sample size of 36 participants would be sufficient per group for a power of 0.8. Seventy-two self-selected participants (32 women), aged between 18 - 45 years ( $Mean = 21$ ,  $SD = 3.2$ ) with no prior relationship to the investigator, were recruited through a convenience sample of staff and students at the University of Warwick. Participants received no payment for partaking in the 40-minute testing session but did have the opportunity to receive their 'lie detection score' and a chance to win a £25 Amazon voucher each if they obtained the lowest score. Participants were equally split and randomly allocated to either the *Innocent* or *Guilty* condition and alternatively allocated to

either the *Investigator 1<sup>st</sup>* or *Investigator 2<sup>nd</sup>* Presentation Order. Two final year, undergraduate psychology students, under supervisor from the author, carried out the data collection for this experiment - one of them played the role of the investigator who administered the CIT and did not know whether the participants was guilty of innocence.

### Procedure

Participants were provided with an overview of the study including their right to withdraw, given the opportunity to ask any questions, and invited to provide consent and demographic information (age and gender).

**Mock Crime.** Participants assigned to the guilty condition watched an 8-minute, 1<sup>st</sup> person perspective, mock crime video filmed and played back in 3D active stereo. Participants were instructed to imagine that they were the culprit in the crime video. In the mock crime (crime items in italics) the culprit began by wandering around a University building before coming across an empty *lecture theatre* with an unattended bag inside (Figure 4.1). The culprit entered the room, masked a CCTV camera using *shaving foam* and then identified that the bag was padlocked. Using *bolt cutters*, the culprit opened the bag to find a *laptop* inside which they stole. The culprit sent a text message to their accomplice *Mike*, which said to meet at 22:00 to exchange the stolen laptop. The culprit then met Mike in a multi-story *carpark* and exchanged the laptop for £60 cash. Participants assigned to the innocent condition also watched an 8-minute, 1<sup>st</sup> person perspective, video filmed and played back in 3D active stereo. However, the innocent participants' protagonist did not commit a crime but instead walked around a town.

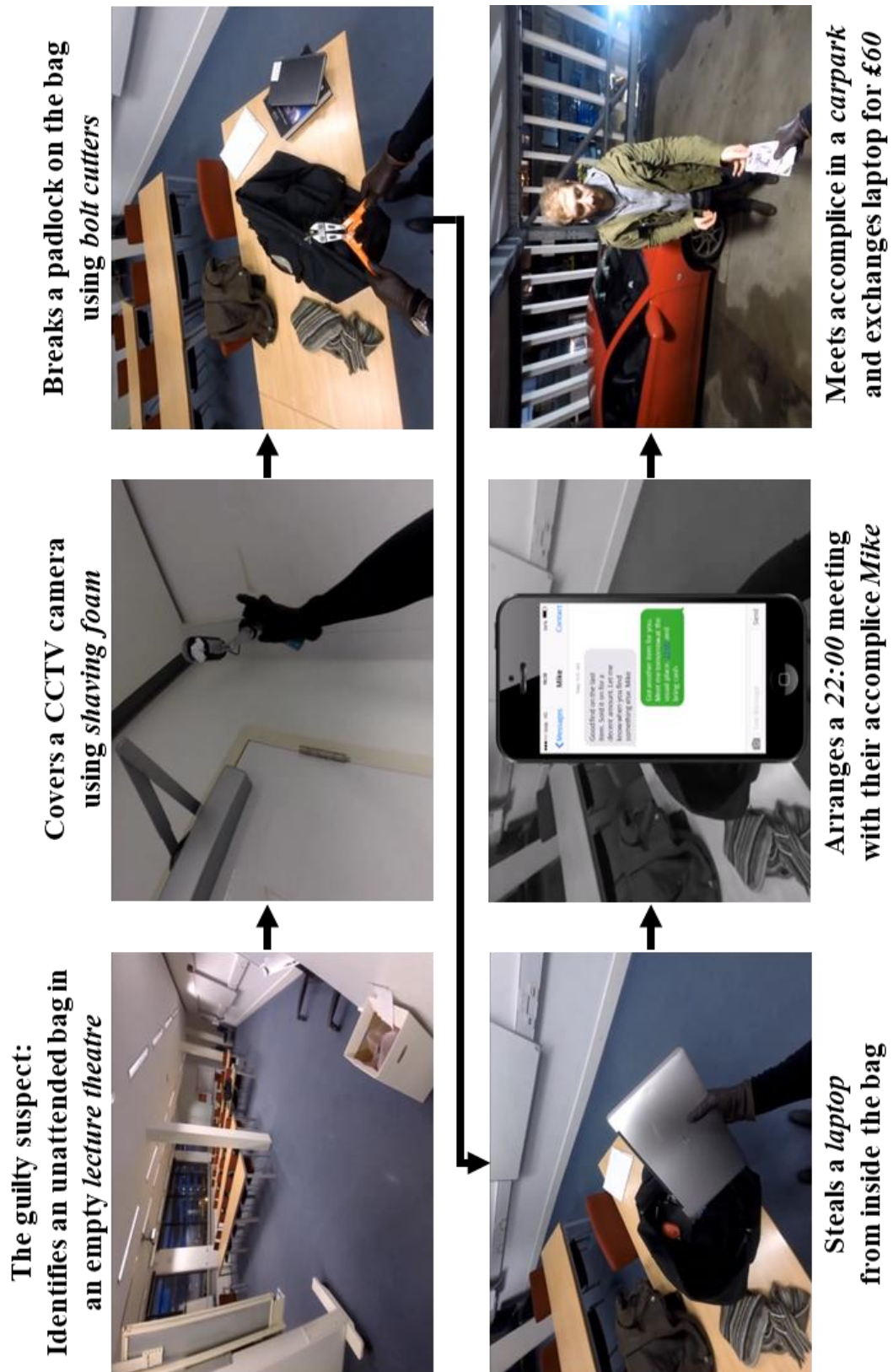


Figure 4.1. Key events in the 1<sup>st</sup> person-perspective mock crime video that guilty suspects view (*crime items in italics*).

**Instructions.** Following the video, participants were asked to imagine that they had been contacted by the authorities informing them that they were suspects in a recent crime and would therefore undertake a lie detection test. They were reminded to try and appear as innocent as possible by simply denying any knowledge of the crime. Participants were then taken to a different cubicle to meet a previously unseen experimenter who played the role of the investigator. Participants were told that although the investigator knew the details about the crime, they did not know whether the participant was ‘guilty’ or not and that the participant should keep this secret (no participants informed the investigator whether they were innocent or guilty). The investigator introduced themselves to the participants before explaining why they had been asked to take a lie detection test. The investigator briefly explained what had happened in the crime without disclosing/reminding the participant of the crime items. They asked the suspect if they knew anything else about the crime and whether they had in fact committed it – all suspects responded ‘no’. The investigator then explained how the CIT worked and connected the physiological sensors to the participant (see below). Participants were reminded that they were being filmed during the CIT and that they should remain as still as possible. The investigator then gave the suspect a sheet with all the CIT questions and accompanying stimuli including all control items and crime items (unlabeled as to not revealed the crime item to potentially innocent participants). Participants were not reminded of, or informed of, which items related to the crime. Previewing all items in the CIT prior to testing is recommended to reduce the novelty of each stimulus therefore removing this potential orienting response confound ([Verschuere & Crombez, 2008](#)). It also allows the experimenter to visually explain the CIT procedure, as well as familiarize participants with the task.

**The CIT.** Suspects were told that eight CIT blocks ([Table 4.1](#)) would be randomly presented with each beginning with a question followed by five images presented sequentially each followed by a blank where the image was removed. Participants were instructed to verbally respond with ‘no’ in response to each item. Participants were not informed about the timing of the CIT. Suspects were informed that the test would be split into two halves each containing four different CIT questions. It was explained that in one half the suspects would see the CIT administered on a computer monitor and in the other half, it would be administered by the investigator. During the computer phase the suspects saw the CIT questions and stimuli as images with text - the investigator was not in the cubicle during this phase. In the investigator phase the CIT would be administered by the investigator using physical photographs. Examples of both presentation types were demonstrated before questions were invited prior to starting the CIT.

*Table 4.1. All eight CIT questions used in this study with corresponding crime and control items (presented as images with text in the study by provided simple as text here).*

| Questions  | Crime Item      | Control Items |              |               |             |
|--|-----------------|---------------|--------------|---------------|-------------|
| <i>If you recall the CCTV camera at the crime scene was masked. Do you recognize any of the following methods used to cover the CCTV camera?</i>                               | Shaving Foam    | Blu Tack      | Duct Tape    | Spray Paint   | Cloth       |
| <i>The stolen item was removed from a padlocked bag. Do you recognize any of the following tools used to disable the lock?</i>   | Bolt Cutters    | Hack Saw      | Wire Cutters | Lock Picks    | Metal Snips |
| <i>The stolen items were handed over to an accomplice at a predetermined location. Do you recognize any of the following as the location as where the handover took place?</i> | Car Park        | Overpass      | Park         | Rail Station  | Town Centre |
| <i>The victim reported the item was stolen from the bag. Do you recognize any of the following as the stolen item?</i>   | Laptop          | Smart Watch   | Headphones   | Tablet        | Phone       |
| <i>We have the accomplice to this theft in custody. Do you recognize any of the following as the accomplice in this crime?</i>   | Mike            | Chris         | James        | Tom           | Steve       |
| <i>The item was stolen from somewhere on University Campus. Do you recognize any of the following as the place where the item was stolen from?</i>                             | Lecture Theatre | Office        | Coffee Shop  | Learning Grid | Library     |
| <i>The accomplice told us of how much they paid for the stolen item. Do you recognize any of these cash amounts as the amount paid for the item?</i>                           | £60             | £100          | £70          | £80           | £50         |
| <i>A witness provided us with the time that the suspects met their accomplice to hand over the item. Do you recognize any of the following times as the meeting time?</i>      | 22:00           | 18:00         | 16:00        | 12:00         | 23:00       |

**Investigator Manipulation.** The guilty condition was randomized by the second experimenter and therefore the investigator did not know whether the suspect was innocent or guilty. Participants were not recruited if they had a pre-existing relationship with the investigator; this was done to mitigate against any unwanted social interactions. The aim in the investigator administered CIT was to make it feel

like a structured interview, whilst still retaining the CIT timing and control. To achieve this a monitor was positioned behind the suspect which cued the investigator to each question and photograph to be presented at each point (Figure 4.2). The computer cued this information using the same structure as the computer presented CIT i.e. randomized CIT blocks and stimuli with defined ISI and stimuli presentation durations. Therefore, for each CIT block, the investigator started by asking the CIT question before presenting the first physical photograph from a folder.

The investigator used a foot peddle to discretely signal to the computer exactly when the investigator had revealed each photograph and when they had removed it. A timer on the investigator's monitor indicated when the photograph required removal and placing back inside the folder. In order to reduce the suspects' perceived waiting period between each photograph, the investigator slowly returned the photograph to the folder to fill the required inter-stimulus interval. Short phrases were used when the photograph was removed and just before it was presented. For example, during removal the photograph the investigator, would respond to suspects' denial "No" with words like "OK", "sure", "right" etc. Then just before each photograph was presented (not including the first one in each block), the investigator asked short questions like "what about this?", "recognize this?", "how about this?", "this one?" etc. Piloting by the investigator was done to ensure they were competent in making the CIT feel like a structured interview where the investigator was both engaging with the suspects and appearing busy during the ISI.



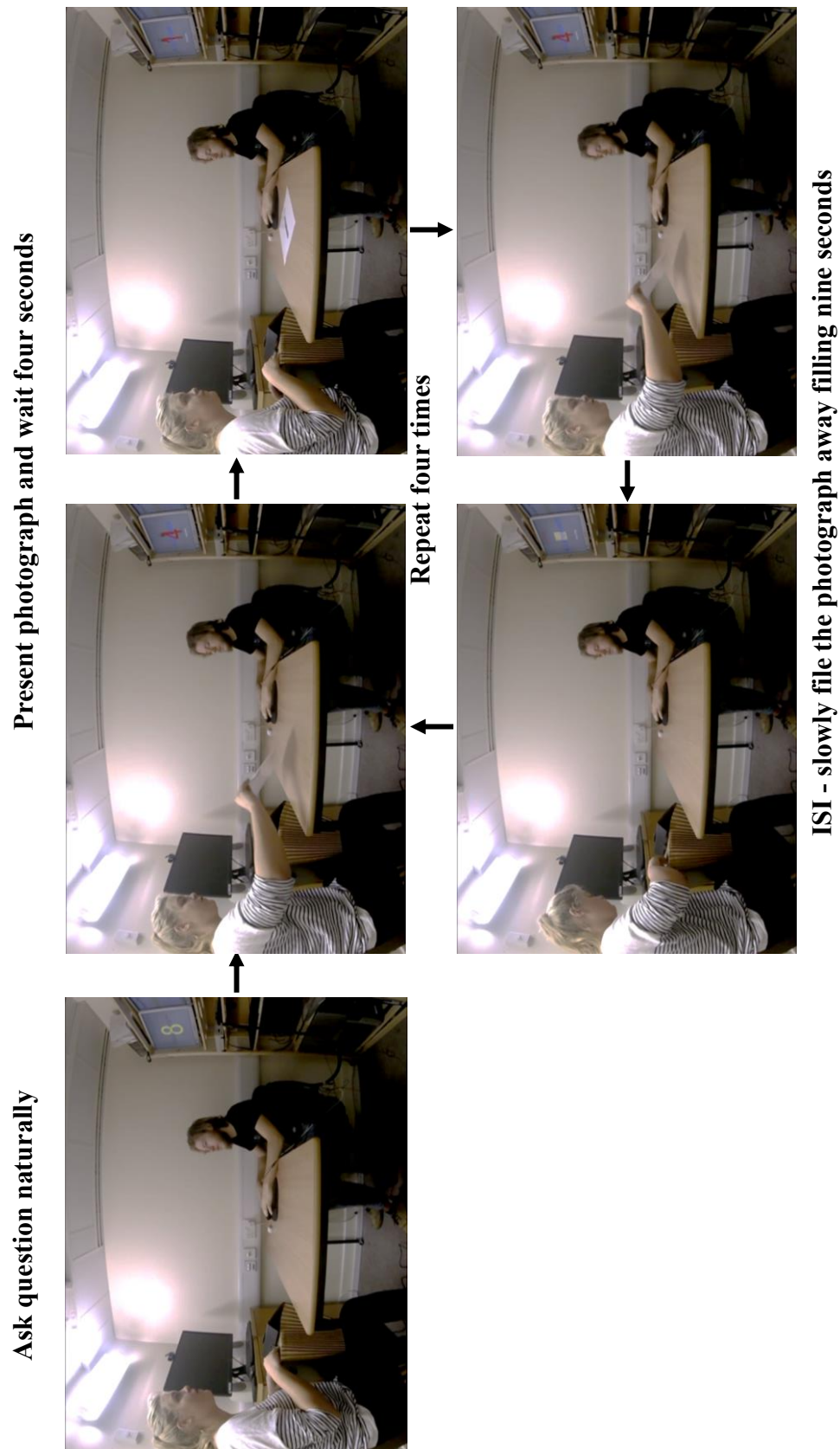


Figure 4.2. Example of a CIT administered by an Investigator (left in images), using photographs and computer cued instructions and timings (right in images).



**Post CIT Questionnaire.** After the CIT, suspects were taken back to see the first experimenter in the original cubicle where they had seen the mock crime video. They were given a paper-based questionnaire consisting of multiple-choice questions to check that they had remembered the crime items if guilty. If they were innocent, they were asked to guess what they thought the crime items might have been. Participants were asked to rate their motivation during the experiment on a scale of 1 (no motivation) to 6 (highly motivated), their stress on a scale of 1 (no stress) to 6 (highly stressed), how immersive they found the mock crime scenario 1 (not immersive) to 6 (highly immersive). Participants were also asked to provide an open answer to the question: *“Did you do anything to try and fool the polygraph test? If you did or didn’t please bullet point below – either case is fine.”* Finally, participants were debriefed.

### **Physiological Data**

Physiological data were recorded and processed in a similar manner as reported by Norman and colleagues, [2020](#). Electrodermal activity (EDA) and heart rate were recorded using an MP36R data acquisition unit (*Biopac Systems Inc*) with pre-gelled disposable Ag/AgCL electrodes (EL507 and EL501 for EDA and heart rate respectively).<sup>1</sup> EDA electrodes were attached to the distal phalanges of the first and middle finger of the non-dominant hand with EDA signals sampled at 1000Hz at  $\times 2000$  gain and filtered using a 66.5Hz low pass filter. For heart rate change ( $\Delta HR$ ), Electrocardiogram (ECG) electrodes were placed in a standard Einthoven Lead I

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<sup>1</sup>Respiration and peripheral vasodilation were also recorded using a respiration belt transducer placed around the thoracic area and a photoplethysmogram transducer placed on the distal phalange of the third finger of the non-dominant hand. However, following a pre-analysis review of the signal, it was decided that neither respiration nor vasodilation would be analysed due to low signal quality.

Configuration: one placed on the ventral side of the dominant wrist; another on the non-dominant lateral aspect of the distal fibula; and the third electrode utilising the EDA ground electrode placed on a non-dominant distal phalange. ECG signals were sampled at 1000Hz at  $\times 1000$  gain, with a 66.5Hz low pass filter and a 0.5Hz high pass filter. Electrodes were attached for approximately 5 minutes before data collection. A webcam was used to record participants from the frontal view to allow for removal of trials where participants made substantial movements.

Skin conductance responses were defined as the difference in absolute magnitude of tonic skin conductance peaks and their respective peak onsets. Skin conductance peaks were identified using an *AcqKnowledge* v4.2 propriety algorithm (Kim, Bang & Kim, 2004) with parameters ensuring peak onsets were within a 0.5-5s window following stimulus presentation and maximum peaks within 10s (Gamer, 2011). For heart rate, an *AcqKnowledge* propriety Heart Rate algorithm was used on the ECG signal to detect R peaks, classify the time interval between them, and automatically filter artefacts. The R-R interval was then converted to instantaneous heart rate (beats per minute) before baseline-correction via subtraction of the 1s mean heart rate prior to stimulus onset. The average baseline-corrected heart rate was calculated between stimulus onset and 15s after stimulus onset, resulting in mean heart rate change. This has previously been shown to outperform other measures of heart rate change when analysing physiological data from the CIT (Gamer, 2011). Due to individual differences in physiological responsiveness, within-subjects standardised scores (z-scores) were calculated for each individual measure (Ben-Shakhar, 1985).

Data from a trial were removed if there was excessive movement (e.g. posture shifts, large head movements, face touching etc. seen on the video) within a

0-2s window prior to individual stimulus onset (klein Selle, Verschuere, Kindt, Meijer & Ben-Shakhar, 2016). Signals were removed if the sensors became dislocated or dislodged during the experiment. Participants with a standard deviation of raw SCR responses below  $0.01\mu\text{S}$  were considered EDA non-responders and their EDA data were removed from analysis (klein Selle et al., 2016). Finally, the first trial in each CIT block, always a control item, was removed prior to analysis as its sole role was to absorb the initial orienting to that CIT item group.

**Exclusions.** From all trials in the data, twenty-two (0.75%) were removed from analysis due to: large movement artifacts; nine posture shifts; six face touches; three large head movements; two coughs; and two large hand movements. In total three participants were considered SCR non-responders and their data were excluded from the SCR analysis (all in the Innocent-Investigator second condition). Finally, due to a technical error, one participants data in the Innocent-Investigator second condition did not record.

## Results

### Skin Conductance Responses

The main finding was that Guilty participants showed larger SCR CIT effects when tested by an Investigator compared to via a Computer but only when tested by the investigator first due to an order effect. Mean normalized SCR CIT effects were analyzed using a 2 (Suspect: Guilty vs. Innocent) x 2 (Presentation: Investigator vs. Computer) x 2 (Order: Investigator 1<sup>st</sup> vs. Investigator 2<sup>nd</sup>) three-way mixed ANOVA with Presentation as the within-subject factor. This revealed a significant main effect of: Suspect,  $F(1, 64) = 65.8, p < .001, MSE = 10.9, \eta_p^2 = .507$  where guilty participants' SCR CIT effects were overall larger than those of innocents' (Figure

4.3); and Presentation,  $F(1, 64) = 11.3, p = .001, MSE = 4.2, \eta_p^2 = .150$ , where overall participants tested by an investigator had larger SCR CIT effects than when tested by a computer; but not presentation Order,  $F(1, 64) = .605, p = .440, MSE = .100, \eta_p^2 = .009$ . There was a significant two-way interaction between: Presentation and Suspect,  $F(1, 64) = 9.65, p = .003, MSE = 3.58, \eta_p^2 = .131$ , where for guilty suspects the overall the SCR CIT effect was larger in the investigator condition; and Suspect and Order,  $F(1, 64) = 4.13, p = .046, MSE = .682, \eta_p^2 = .061$ , where the SCR CIT effect differed more between Order groups for innocent participants. There was no two-way interaction between Presentation and Order,  $F(1, 64) = .039, p = .843, MSE = .015, \eta_p^2 = .001$ . The three-way interaction was however significant,  $F(1, 64) = 5.59, p = .021, MSE = 2.07, \eta_p^2 = .080$ .

Given the unexpected order interactions, separate follow-up ANOVAs were conducted for each presentation order. For participants tested by the investigator first, there was a significant main effect of: Suspect,  $F(1, 34) = 24.6, p < .001, MSE = 5.12, \eta_p^2 = .420$ , where guilty participant's SCR CIT effects were overall larger than innocents and; Presentation,  $F(1, 34) = 8.81, p = .005, MSE = 2.52, \eta_p^2 = .206$ , where both guilty and innocent participants tested by an investigator had larger SCR CIT effects than when tested by a computer. Additionally, there was a significant two-way interaction between Presentation and Suspect,  $F(1, 34) = 20.8, p < .001, MSE = 5.95, \eta_p^2 = .379$ , driven by guilty participants having larger SCR CIT effects when tested by an Investigator compared to a Computer,  $t(17) = 5.04, p < .001, d = 1.19$  ( $MD = .949$ ). Presentation had no impact on SCR CIT effects for innocent participants,  $t(17) = 1.19, p = .249, d = .282$  ( $MD = .200$ ). For participants tested by the investigator second, there was also a significant main effect of Suspect,  $F(1, 30) = 68.2, p < .001, MSE = 7.96, \eta_p^2 = .695$ , where guilty participant's SCR CIT effects

were overall larger than innocents. However, no main effect of Presentation was found,  $F(1, 30) = 3.73, p = .063, MSE = 1.74, \eta_p^2 = .111$ . There was also no significant two-way interaction between Presentation and Suspect,  $F(1, 30) = .205, p = .654, MSE = .096, \eta_p^2 = .007$ .

Finally, to remove the order factor and consequently change to the design fully between-subjects, the second testing epoch was removed. Mean normalized SCR CIT effects were analyzed using a 2 (Suspect: Guilty vs. Innocent) x 2 (Presentation: Investigator vs. Computer) x two-way ANOVA. This revealed a significant main effect of: Suspect,  $F(1, 64) = 40.7, p < .001, MSE = 11.2, \eta_p^2 = .389$  where overall guilty participant's SCR CIT effects were larger than those of innocents' (Figure 4.4); and Presentation,  $F(1, 64) = 10.1, p = .002, MSE = 2.80, \eta_p^2 = .137$ , where overall participants tested by an investigator had larger SCR CIT effects than when tested by a computer. However, this appears to be driven solely by the guilty suspects,  $t(34) = 2.94, p = .006, d = .978 (MD = .592)$  as there was no presentation effect for innocent participants,  $t(30) = 1.51, p = .141, d = 0.53 (MD = .224)$ . However, was no significant two-way interaction between Presentation and Suspect,  $F(1, 64) = 2.06, p = .156, MSE = .568, \eta_p^2 = .031$ .

### Heart Rate Change

The main finding was that guilty participants showed larger  $\Delta HR$  CIT effects compared to innocent however there was no interaction with presentation. Mean normalized  $\Delta HR$  were analyzed in the same way as SCR CIT effects. This revealed a significant main effect of Suspect,  $F(1, 67) = 11.7, p = .001, MSE = 2.57, \eta_p^2 = .148$  where overall guilty participants'  $\Delta HR$  CIT effects were larger (i.e. greater heart rate deceleration) than innocent participants (Figure 4.5). There was no significant main effect of Presentation,  $F(1, 67) = .337, p = .564, MSE = .131, \eta_p^2 = .005$ ; or

presentation Order,  $F(1, 67) = .037, p = .848, MSE = .008, \eta_p^2 = .001$ . There was no significant two-way interaction between Suspect and Order,  $F(1, 67) = 1.63, p = .206, MSE = .359, \eta_p^2 = .024$ ; Presentation and Suspect,  $F(1, 67) = .447, p = .506, MSE = .174, \eta_p^2 = .007$ ; or Presentation and Order,  $F(1, 67) = .701, p = .406, MSE = .273, \eta_p^2 = .010$ . Finally, there was no significant three-way interaction,  $F(1, 67) = 1.19, p = .280, MSE = .462, \eta_p^2 = .017$ .

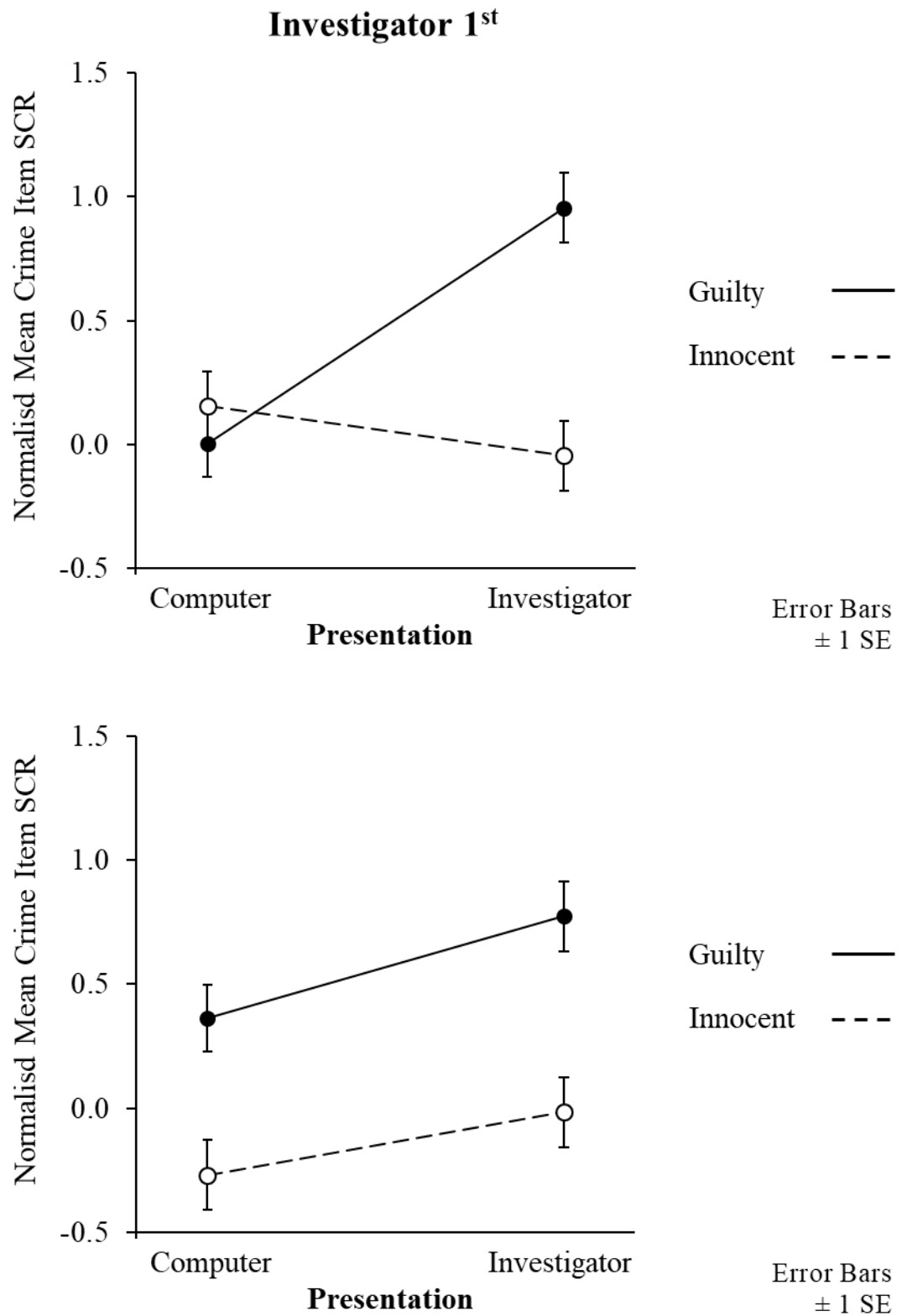


Figure 4.3. Experiment 1 - Mean normalized SCR CIT effect as a function of Suspect, presentation Order and Presentation.

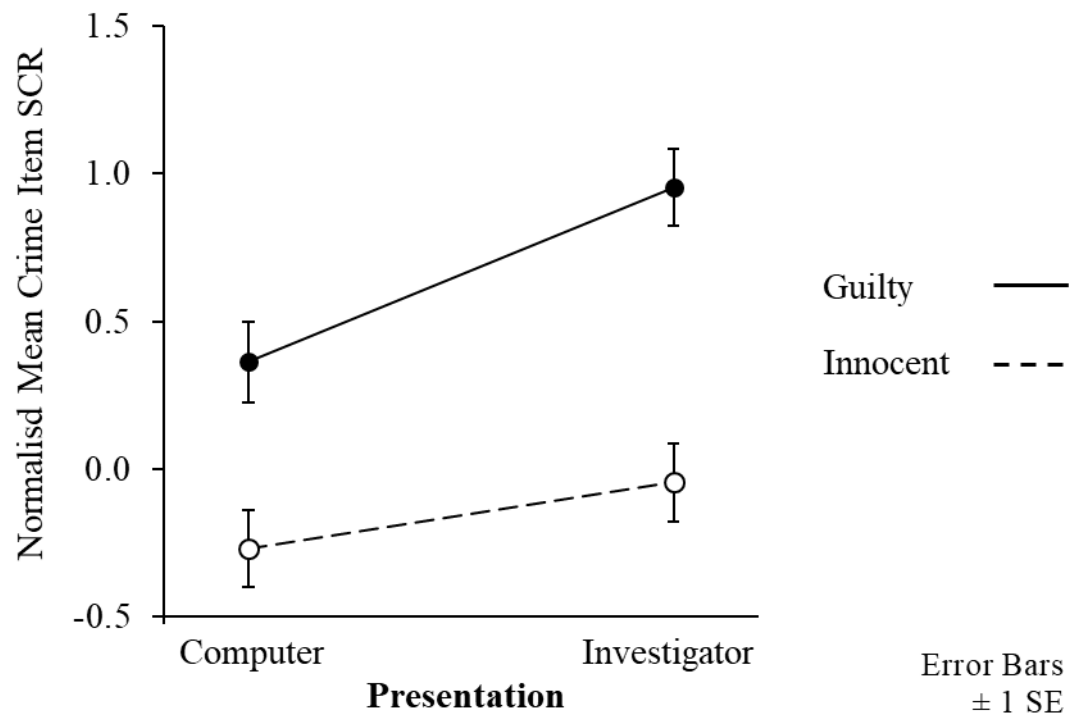


Figure 4.4. Experiment 1 - Mean normalized SCR CIT effect as a function of Suspect and presentation for the first block only.



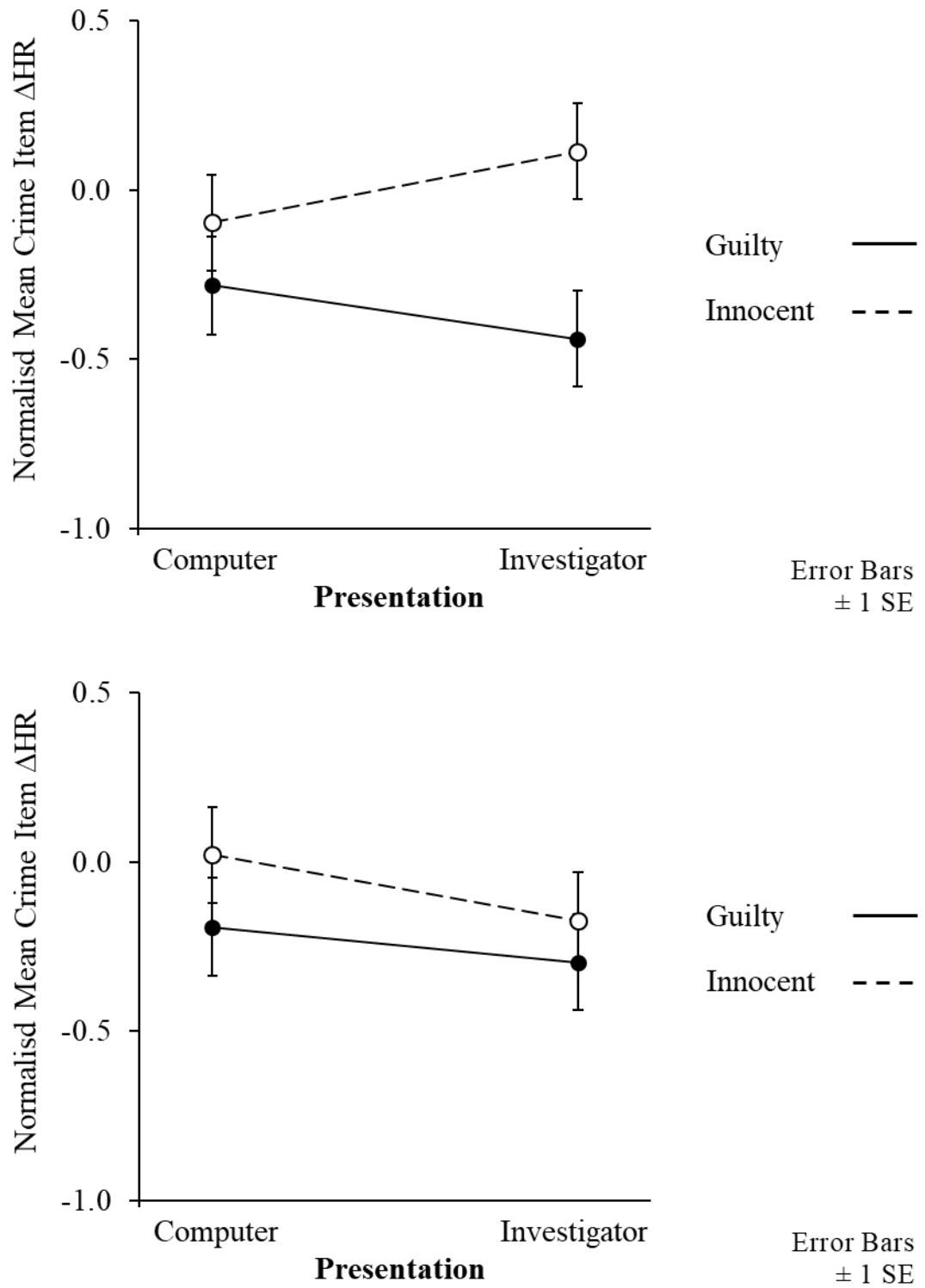


Figure 4.5. Experiment 1 - Mean normalized Heart Rate change CIT effect as a function of Suspect, Presentation and Order.

### Post CIT Questionnaire

No additional factors measured in this study significantly differed across the between-subjects condition, suggesting that it was unlikely that they influenced the above findings. Participants correctly recalled 96% of crime items, with twelve participants forgetting one of the eight crime items, four participants forgetting two and one participant forgetting three. Guilty participants reported the mock video stimuli as very immersive,  $Mean = 5.4$ ,  $SD = 0.7$  (Scale = 1<sub>not</sub> to 6<sub>very</sub>), and this was larger than immersion ratings for innocent participants,  $Mean = 4.2$ ,  $SD = 1.3$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>),  $t(69) = 5.18$ ,  $p < .001$ ,  $d = 1.23$ , ( $MD = 1.3$ ). Overall participants' self-reported motivation was high with  $Mean = 5.2$ ,  $SD = 0.9$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>). Mean self-reported motivation was analysed using a 2 (Suspect: Guilty vs. Innocent)  $\times$  2 (Order: Investigator 1<sup>st</sup> vs. Investigator 2<sup>nd</sup>) ANOVA. This revealed a significant main effect of Suspect,  $F(1, 67) = 4.1$ ,  $MSE = 3.45$ ,  $p = .047$ ,  $\eta_p^2 = .058$ , with guilty participants self-reporting as more motivated ( $M = 5.4$ ,  $SD = 1.0$ ) than innocent participants ( $M = 5.0$ ,  $SD = 0.8$ ). However, there was no significant interaction between Suspect and Order,  $F(1, 67) = .276$ ,  $MSE = .232$ ,  $p = .601$ ,  $\eta_p^2 = .004$ , nor of Order,  $F(1, 67) = .276$ ,  $MSE = .232$ ,  $p = .601$ ,  $\eta_p^2 = .004$ . Overall, participants' self-reported stress during the CIT was low with  $Mean = 3.0$ ,  $SD = 1.4$  (range = 1<sub>no stress</sub> to 6<sub>highly stressed</sub>). Mean self-reported stress during the CIT was analysed using a 2 (Suspect: Guilty vs. Innocent)  $\times$  2 (Order: Investigator 1<sup>st</sup> vs. Investigator 2<sup>nd</sup>) ANOVA. This revealed a significant main effect of Suspect,  $F(1, 67) = 5.0$ ,  $MSE = 9.0$ ,  $p = .028$ ,  $\eta_p^2 = .070$ , with guilty participants self-reporting as more stressed during the CIT ( $M = 3.3$ ,  $SD = 1.5$ ) than innocent participants ( $M = 2.6$ ,  $SD = 1.2$ ). However, there was no significant interaction between Suspect and Order,  $F(1, 67) = 1.89$ ,  $MSE = 3.38$ ,  $p = .174$ ,  $\eta_p^2 = .027$ , nor of Order,  $F(1, 67) = .454$ ,  $MSE = .813$ ,  $p$

= .503,  $\eta_p^2 = .007$ . Twenty guilty participants (28%), ten in each Order condition, reported using some form of countermeasure to fool the test: twelve tried to control their breathing; four thought about something else; two engaged in physical movement; and two gave special attention to the control items.

### **Discussion**

In this experiment, participants, either aware of crime information (guilty) or not (innocent), underwent a CIT administered by a computer and a human investigator. Perhaps unexpectedly, the order in which participants were tested by the investigator had a significant impact on the results. When guilty participants were tested by the investigator first, the SCR CIT effect was larger when the investigator administered the CIT. No investigator effects were found when the CIT was administered by an investigator second. Additionally, no investigator effects were found when only considering the first CIT block seen by each participant, i.e. just investigator first or computer first. Other than the well-documented finding that the CIT effect is larger for guilty participants and negligible for innocents, seen for both SCR and  $\Delta HR$ , no investigator effect for  $\Delta HR$  CIT effect was found. Finally, there were no differences for self-reported CIT motivation, stress and countermeasure use between our order conditions, suggesting these factors were unlikely to have impacted our CIT effect findings – we note that these factors have been found to modulate the CIT effect which are investigated further in Chapter 8. Encouragingly, guilty participants rated the mock crime videos as highly immersive, suggesting the use of 1<sup>st</sup> person perspective videos, filmed and played in 3D, offer an immersive and possible more ecologically valid mock crime compared to imagining and learning text or images of 2D static items.

The findings are contrary to the prediction that an investigator administering the CIT and knowledgeable about the crime details, would have an effect on innocent unknowledgeable participants. Findings in social psychology, and indeed eyewitness line-up research, often find Expectancy effects whereby the investigator's expectations or knowledge about the desired outcome or target stimuli, influence the participants' behavior ([Rosenthal, 2002](#)). However, this was not found for innocent participants, suggesting the investigator did not significantly influence the participants' physiological CIT effect.

However, when considering guilty participants in this experiment, there was an investigator effect when the investigator condition was administered first. However, on examination of [Figure 4.3](#), this appears due to be a result of the SCR CIT effect decreasing for guilty participants during the computer presented phases when this phase follows the investigator condition. This suggest that having an investigator conduct the CIT first might negatively impacts the computer phase afterwards. In light of this possible carry over effect, it seems appropriate to explore the investigator effect using a fully between-subjects design to remove any carry over.

### **Experiment 2 - Replication**

As a replication, and due to the order effects revealed in Experiment 1, Experiment 2 was conducted as a between-subjects design where suspects received all eight questions in the CIT by either the investigator or the computer. Therefore, the Order factor was removed, and the experiment changed to a 2 (Suspect: Guilty vs. Innocent) x 2 (Investigator vs. Computer) between-subjects design. In addition, the CIT image duration was increased to 6s and ISI to 12s, allowing more time for the investigator to administer the CIT - this also allowed for the ECG analysis window to increase to 18s. Additionally, two different experimenters, and consequently a different investigator, were recruited to collect the data for this experiment. The remaining method was identical to Experiment 1 with the exceptions described below. Finally, a combined analysis using data from both Experiments 1 and 2 was planned to follow this replication.

#### **Method**

##### **Participants**

Similarly, to Experiment 1, eighty self-selected participants (55 women), aged between 18 - 32 years ( $Mean = 20.7$ ,  $SD = 1.7$ ), without a prior relationship with the investigator, were recruited through a convenience sample of staff and students at the University of Warwick. Participants received no payment for partaking in the 45-minute testing session but did have the opportunity to receive their 'lie detection score' and a chance to win a £25 Amazon voucher each if they obtained the lowest score. Participants were equally split and randomly allocated to either the Innocent or Guilty condition and alternatively allocated to the Investigator or Computer condition. Two different final year undergraduate psychology students,

under close supervisor from the first author, carried out this experiment with one playing the role of the investigator.

**Exclusions.** From all trials in the data, fifteen (0.23%) were removed from analysis due to large movement artifacts; Eleven large head movements and four posture shifts. A technical error in the physiological data collection resulted in the removal of all data for one participant in the innocent-investigator condition. Finally, three participants were considered SCR non-responders and their data were excluded from the SCR analysis (one from each condition except guilty-computer).

## Results

### Skin Conductance Responses

The main finding was that guilty participants showed larger SCR CIT effects when tested by an Investigator compared to a Computer. Mean normalized SCR CIT effects were analyzed using a 2 (Suspect: Guilty vs. Innocent) x 2 (Presentation: Investigator vs. Computer) two-way ANOVA. This revealed a significant main effect of: Suspect,  $F(1, 72) = 34.0, p < .001, MSE = 3.44, \eta_p^2 = .320$  where overall guilty participant's SCR CIT effects were larger than those of innocents' (Figure 4.6); but not of Presentation,  $F(1, 72) = .875, p = .353, MSE = .089, \eta_p^2 = .012$ . There was a significant two-way interaction between: Presentation and Suspect,  $F(1, 72) = 6.11, p = .016, MSE = .619, \eta_p^2 = .078$ . Post hoc t-tests revealed that this was driven by Guilty participants having larger SCR CIT effects when tested by an Investigator compared to via Computer,  $t(35) = 2.4, p = .023, d = .783 (MD = .249)$  with no difference for Innocent participants,  $t(37) = 1.10, p = .278, d = .352 (MD = .112)$ .

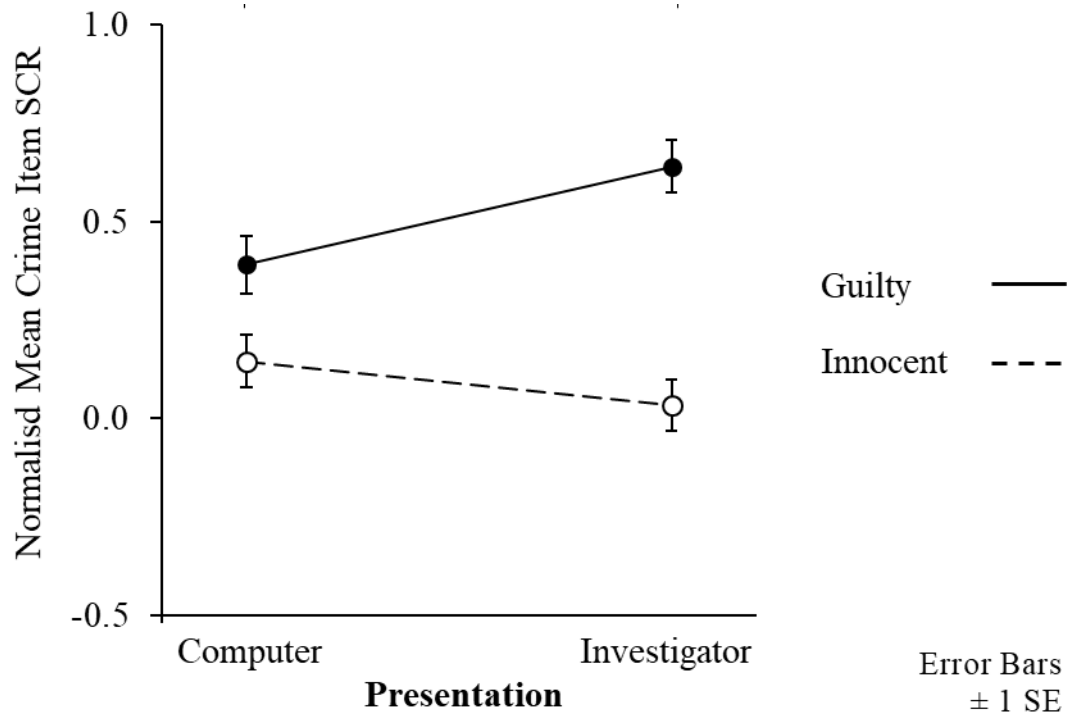


Figure 4.6. Experiment 2 - Mean normalized SCR CIT effect as a function of Suspect and Presentation condition.

### Heart Rate Change

The main finding was that guilty participants showed larger  $\Delta$ HR CIT effects compared to innocent however there was no interaction with presentation. Mean normalized  $\Delta$ HR CIT effects were analyzed in the same way as SCR above. This revealed a main effect of: Suspect,  $F(1, 73) = 7.44, p = .008, MSE = .789, \eta_p^2 = .092$ , where overall guilty participants'  $\Delta$ HR CIT effects were larger (i.e. greater heart rate deceleration) than those of innocents' (Figure 4.7); but no significant effect of Presentation,  $F(1, 73) = 2.52, p = .117, MSE = .268, \eta_p^2 = .033$  or interaction between Presentation and Suspect,  $F(1, 73) = .081, p = .776, MSE = .01, \eta_p^2 = .001$ .

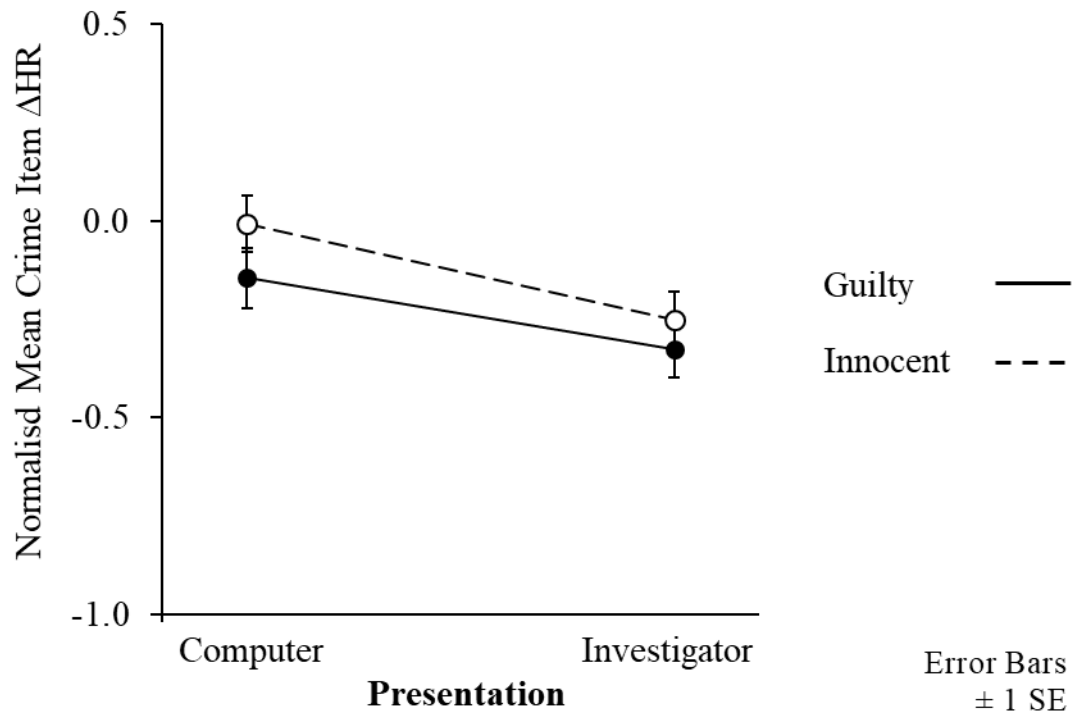


Figure 4.7. Experiment 2 - Mean normalized Heart Rate change as a function of Suspect and Presentation condition.

### Post CIT Questionnaire

Like Experiment 1, no additional factors significantly differed across between-subjects conditions suggesting that it was unlikely that they influenced the above findings. Participants correctly recalled 97% of crime items, with eleven participants forgetting one of the eight crime items and four participants forgetting two. Guilty participants reported the mock video stimuli as immersive, Mean = 4.7,  $SD = 1.0$  (Scale = 1<sub>not</sub> to 6<sub>very</sub>), and this was marginally larger than immersion ratings from innocent participants, Mean = 4.2,  $SD = 1.1$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>),  $t(77) = 1.94$ ,  $p = .055$ ,  $d = .438$ , ( $MD = .467$ ). Overall participants' self-reported motivation was high with Mean = 4.9,  $SD = 0.9$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>). Mean self-reported motivation was analysed using a 2 (Suspect: Guilty vs. Innocent)  $\times$  2 (Presentation: Investigator vs. Computer) ANOVA. This revealed a main effect of Suspect,  $F(1, 75) = 4.12$ ,  $MSE = 3.1$ ,  $p = .046$ ,  $\eta_p^2 = .052$ , with guilty participants self-reporting as more



motivated ( $M = 5.1$ ,  $SD = 0.8$ ) than innocent participants ( $M = 4.7$ ,  $SD = 1.0$ ); but no effect of Presentation,  $F(1, 75) = 1.64$ ,  $MSE = 1.24$ ,  $p = .205$ ,  $\eta_p^2 = .021$ . There was no interaction between Suspect and Presentation,  $F(1, 75) = .359$ ,  $MSE = .272$ ,  $p = .551$ ,  $\eta_p^2 = .005$ . Overall, participants' self-reported stress during the CIT was low with Mean = 2.9,  $SD = 1.4$  (range = 1<sub>no stress</sub> to 6<sub>highly stressed</sub>). Mean self-reported stress was analysed using a 2 (Suspect: Guilty vs. Innocent)  $\times$  2 (Presentation: Investigator vs. Computer) ANOVA. This revealed a significant main effect of Suspect,  $F(1, 75) = 11.3$ ,  $MSE = 20.0$ ,  $p = .001$ ,  $\eta_p^2 = .131$ , with guilty participants self-reporting as more stressed ( $M = 3.5$ ,  $SD = 1.5$ ) than innocent participants ( $M = 2.5$ ,  $SD = 1.2$ ); and no effect of Presentation,  $F(1, 75) = 2.2$ ,  $MSE = 4.0$ ,  $p = .139$ ,  $\eta_p^2 = .029$ . There was no interaction between Suspect and Presentation,  $F(1, 75) = .370$ ,  $MSE = .656$ ,  $p = .545$ ,  $\eta_p^2 = .005$ . Twenty Guilty participants (25%), ten in the investigator condition, reported using some form of countermeasure to fool the test: Nine tried to control their breathing; three tried to remain calm; three thought about something else; two gave special attention to the control items; and one engaged in physical movement.

## Discussion

The order effect found in Experiment 1 made it difficult to determine the impact of having an investigator administer the CIT. Therefore, Experiment 2 was conducted as a close replication but used a fully between-subjects design. Participants, aware of crime details or not, underwent a CIT administered either by a computer or by an investigator. The results in Experiment 2 revealed that for innocent participants, there was no effect of being tested by an investigator or computer on either SCR or  $\Delta HR$  and, for guilty participants, no difference for the  $\Delta HR$  CIT effect. Again, these findings suggest that the CIT effect may not be modulated by expectancy effects found in previous studies ([Rosenthal, 2002](#);

Richard, Bond Jr, & Stokes-Zoota, 2003). However, for guilty participants where there was a larger SCR CIT effects when tested by an Investigator compared to a Computer. Finally, no differences were revealed for self-reported CIT motivation, stress and countermeasure use between groups suggesting these factors were unlikely to have impacted the CIT findings; additionally, self-reported immersion for the mock crime video was high.

### **Combined Analysis**

Both Experiments 1 and 2 used similar methodologies, with the main exception that Experiment 1 manipulated the presentation condition using a within-subjects design and Experiment 2 used a between-subjects design. Therefore, to increase power and conduct additional analysis, the data from Experiments 1 and 2 were combined. This was achieved by removing the second block in Experiment 1, thereby making it a fully between-subject design like Experiment 2 and including Experiment as an addition factor. Null investigator effects were then followed up using Bayesian statistics and a signal detection analysis was conducted to compare the detection rates for both presentation conditions.

### **Skin Conductance Responses**

The main finding was that Guilty participants showed larger SCR CIT effects when tested by an Investigator compared to via a Computer. Mean normalized SCR CIT effects were analyzed using a 2 (Suspect: Guilty vs. Innocent) x 2 (Presentation: Investigator vs. Computer) x 2 (Experiment: 1 vs. 2) three-way fully between-subjects ANOVA. This revealed a significant main effect of: Suspect,  $F(1, 136) = 75.1, p < .001, MSE = 13.8, \eta_p^2 = .356$ , where guilty participants' overall SCR CIT effects were larger than those of innocents' (Figure 4.8); and Presentation,  $F(1, 136)$

$= 11.0, p = .001, MSE = 2.02, \eta_p^2 = .075$ , where overall participants tested by an investigator had larger SCR CIT effects than when tested by a computer. There was no main effect of Experiment,  $F(1, 136) = .545, p = .462, MSE = .100, \eta_p^2 = .004$ . There was a significant two-way interaction between Presentation and Suspect,  $F(1, 136) = 6.46, p = .012, MSE = 1.18, \eta_p^2 = .045$ . Post hoc t-tests revealed that this was driven by guilty participants having larger SCR CIT effects when tested by an Investigator compared to by a Computer,  $t(71) = 3.68, p < .001, d = .861$  ( $MD = .420$ ) with no difference for Innocent participants,  $t(69) = .22, p = .827, d = .052$  ( $MD = .020$ ). There was a significant two-way interaction between Presentation and Experiment,  $F(1, 136) = 5.61, p = .019, MSE = 1.03, \eta_p^2 = .040$ , where the overall difference in SCR CIT effect between the investigator and computer condition was larger in Experiment 1; and Suspect and Experiment,  $F(1, 136) = 7.44, p = .007, MSE = 1.36, \eta_p^2 = .052$ , where the overall difference in SCR CIT effect between the guilty and innocent participants was larger in Experiment 1. Finally, there was no three-way interaction,  $F(1, 136) = .001, p = .982, MSE \approx 0, \eta_p^2 \approx 0$ .

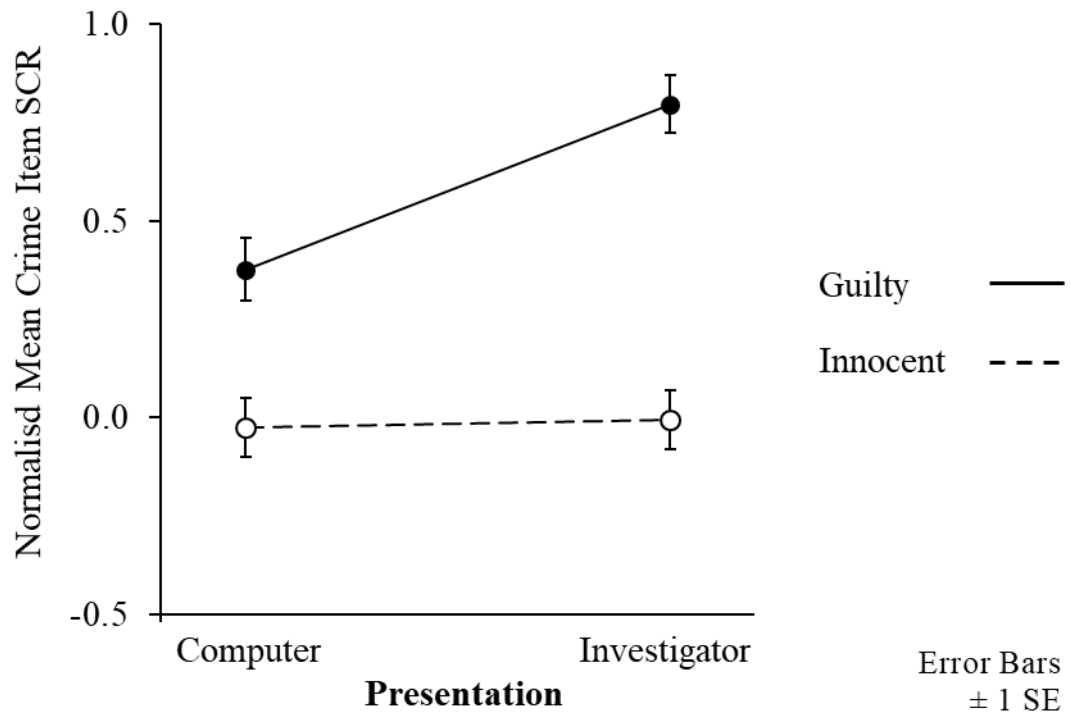


Figure 4.8. Experiments 1 and 2 combined - mean normalized SCR CIT effect as a function of Suspect and Presentation condition.

### Heart Rate Change

The main finding was that Guilty participants showed larger  $\Delta$ HR CIT effects than innocent participants. Mean normalized  $\Delta$ HR CIT effects were analyzed in the same way as SCR CIT effect above. This revealed a significant main effect of Suspect,  $F(1, 140) = 18.7, p < .001, MSE = 3.17, \eta_p^2 = .118$  where overall guilty participants'  $\Delta$ HR CIT effects were larger (i.e. greater heart rate deceleration) than innocents' (Figure 4.9) but not of Presentation,  $F(1, 140) = 2.05, p = .155, MSE = .347, \eta_p^2 = .014$ , or Experiment,  $F(1, 140) = .601, p = .439, MSE = .102, \eta_p^2 = .004$ . There were no significant two-way interactions between: Presentation and Suspect,  $F(1, 140) = 1.22, p = .272, MSE = .206, \eta_p^2 = .009$ ; Presentation and Experiment,  $F(1, 140) = .096, p = .757, MSE = .016, \eta_p^2 = .001$ ; or Suspect and Experiment,  $F(1, 140) = 1.78, p = .184, MSE = .302, \eta_p^2 = .013$ . The three-way

interaction was also non-significant,  $F(1, 140) = 2.0$ ,  $p = .159$ ,  $MSE = .340$ ,  $\eta_p^2 = .014$ .

### Bayesian Analysis

Where frequentist analysis reveals a non-significant difference, the Bayes factor  $BF_{01}$  is sometimes reported to quantify the degree to which the data support the null hypothesis (Wagenmakers et al. 2018). Therefore, to elaborate on the lack of significant difference between innocent participants' CIT effect when tested by an investigator versus computer, a Bayes paired t-test was conducted using JASP software 0.10.2 (JASP Team, 2018) with a default Cauchy prior width of 0.7. For innocent participants, the difference between presentation conditions for SCR and  $\Delta HR$  were,  $BF_{01} = 4.0$  (for both) implying 'moderate evidence for the null hypothesis' (Jefferys, 1961) that the investigator had no influence on CIT effects.

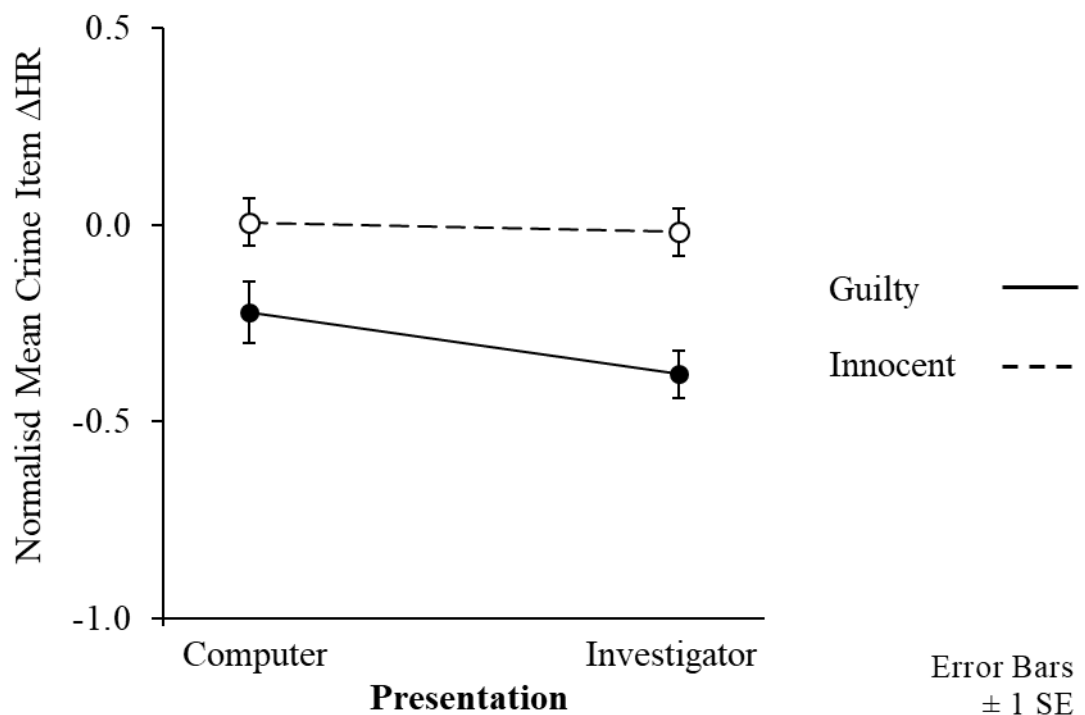


Figure 4.9. Experiments 1 and 2 combined - mean normalized Heart Rate change as a function of Suspect and Presentation condition.

### Signal Detection Analysis

To assess the efficiency of detection, signal detection analysis was used to determine the degree of separation between the participants in our experiment who were considered ‘guilty’ and an equivalent innocent group. Given no innocent participants were tested, data for innocent participants were simulated by the standard method used in the CIT literature (e.g. [Carmel, Dayan, Naveh, Raveh, & Ben-Shakhar, 2003](#); [Visu-Petra et al, 2013](#); and [Meijer, Smulders, Johnston, & Merckelbach, 2007](#)). This approach assumes that innocent participants, not knowledgeable about the crime item, respond in the same manner to all items. Therefore, the procedure for simulating innocent participant data involves drawing random SCRs from a standard normal distribution. This is conducted for each trial with one trial in five then randomly chosen to represent the simulated crime item. Once calculated for each participant, an ROC was generated to approximate the signal detection using within-subject scored CIT effect for the ‘guilty’ group and for the normalized simulated ‘innocent’ group. ROCs are based on a comparison of two detection score distributions, where detection score of guilty was defined as the mean normalized difference between crime and control items and the detection score of innocents was similarly defined but using the simulated crime and control responses.

As shown in [Figure 4.10](#), the curves are close to the upper left-hand corner of the ROC which indicates high overall accuracy ([Zweig & Campbell, 1993](#)). The area under this curve (*AUC*) allows an objective measure of diagnosticity - the accuracy trade-off between the test sensitivity and specificity. An *AUC* of 0.5 suggests no discrimination, 0.7-0.8 is considered fair, 0.8-0.9 is excellent, and 0.9+ is outstanding ([Hosmer Jr, Lemeshow, & Sturdivant, 2000](#)). In the Investigator condition, the SCR CIT effect’s *AUC* = .925, indicating an outstanding diagnostic test. This figure

meshes with the group level (i.e. Guilty-Innocent difference) effect size Cohens'  $d = 1.92$  which represents a large effect. In the Computer condition the SCR CIT effect's  $AUC = .733$  indicating a fair diagnostic test and the effect size was  $d = .868$  indicating a large effect. The detection rate in Investigator was significantly better than the Computer condition,  $AUC\ diff = .192$ ,  $SE = .066$ ,  $z = 2.91$ ,  $p = .003$ . Finally, collapsed over conditions, heart rate CIT effect diagnosticity was outstanding,  $AUC = .937$ ,  $d = .716$ .

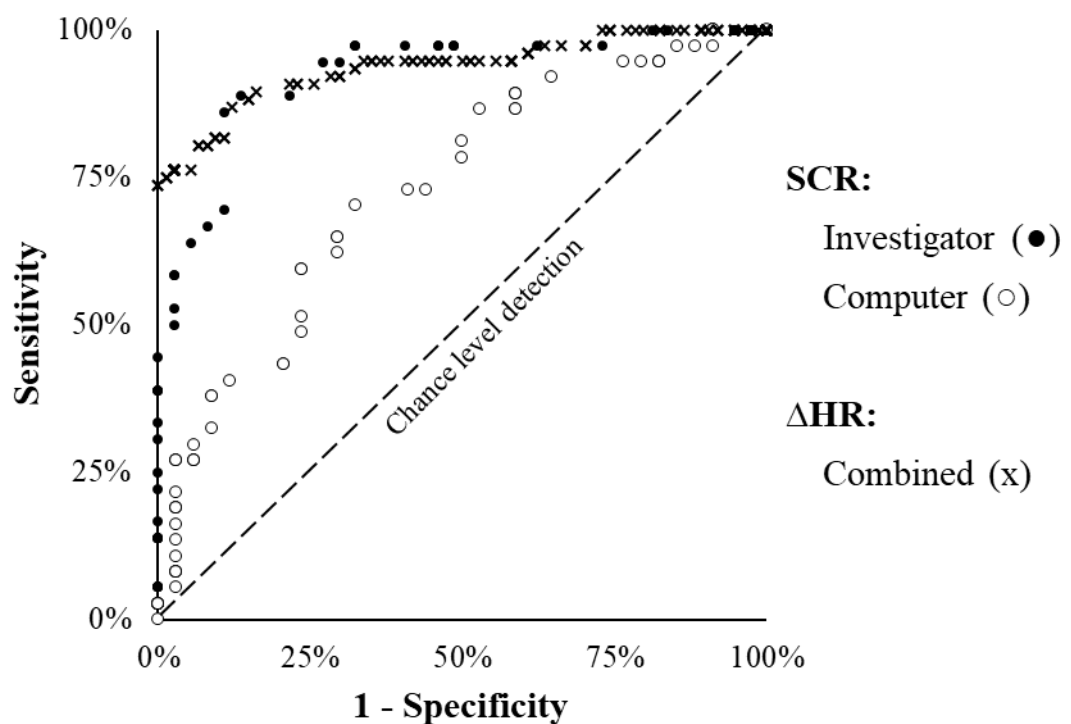


Figure 4.10. Experiments 1 and 2 combined signal detection curve (ROC) showing the detection sensitivity and specificity between guilty and innocent participants for SCR between participants tested by an investigator and computer

### General Discussion

Findings from social psychology (e.g., [Rosenthal, 2002](#); [Richard, Bond Jr, & Stokes-Zoota, 2003](#)) caution against using human investigators, knowledgeable about a crime, to administer forensic assessments of the memory of eyewitness ([Perlini & Silvaggio, 2007](#); [Phillips et al., 1999](#); [Douglass, Smith & Fraser-Thill, 2005](#)) or suspects ([Meijer, Verschuere, & Ben-Shakhar, 2011, p. 300](#)). However, findings from deception (e.g. the *Motivational Impairment Effect*, [DePaulo et al., 2003](#)), memory research (e.g., increased CIT effect with a virtual investigator, [Ambach et al., 2012](#)), and the apparent difficulty of face-to-face lying ([Hancock, Woodworth, & Goorha, 2010](#)) suggest that using an investigator may be beneficial.

In the current study, the effect of having a human investigator administer a CIT was experimentally tested. Innocent and guilty suspects watched first-person perspective videos, the latter of a mock crime, before taking a CIT with SCR and heart rate recorded. The CIT was administered by either a human investigator or a computer using both a within-subjects (Experiment 1) and between-subjects (Experiment 2) design. The investigator, unaware of the suspect's guilt, sat opposite the participants and asked each CIT question before presenting CIT stimuli as photographs. The results in both experiments revealed that for innocent participants, there was no significant difference on CIT effects when either administered a CIT by an investigator for either SCR or  $\Delta$ HR. This was also true for guilty participants for  $\Delta$ HR. However, when considering the SCR CIT effect, for guilty participants there was an investigator effect whereby the SCR CIT effect was larger when an investigator administered the CIT compared to a computer.

These findings held true for SCR and  $\Delta$ HR after combining the data from Experiments 1 (first block only) and Experiment 2. To further test the null



investigator effect found for innocent participants, a Bayesian t-test was conducted which provided moderate evidence that the investigator had no impact on either the SCR or  $\Delta$ HR CIT effects. Finally, a signal detection analysis revealed that CIT diagnosticity was greater when participants were administered the CIT by an investigator. Overall, the results indicate that when using an investigator, aware of the crime details, to administer a physiological CIT face-to-face, concealed information detection increases with little change in false positive rates.

Expectancy effects cannot account for these findings because innocent participants were not affected by the investigator, despite the investigator knowing about the crime. A range of experiments have found expectancy effects (e.g., [Rosenthal, 2002](#); [Richard, Bond Jr, & Stokes-Zoota, 2003](#)), including those assessing the impact of single-blind administrators in eyewitness line-up research ([Perlini & Silvaggio, 2007](#); [Phillips, McAuliff, Kovera, and Cutler, 1999](#); [Douglass, Smith & Fraser-Thill, 2005](#); [Greathouse & Kovera, 2009](#); [Haw & Fisher, 2004](#)), although expectancy effects are often small and not always found ([Rosenthal & Rubin, 1978](#)). Even when data from both experiments in this study were combined, providing seventy-one innocent participants, a Bayesian t-test provided evidence for no investigator influence. One explanation for this could simply be that the investigators in this study did not unintentionally cue the crime items. Both investigators were aware of the issues of experimenter effects. This may have made them overly cautious when presenting each CIT photograph to the suspects, consequently reducing any influence on the participant. A follow up study could systematically manipulate the cues given by an investigator in a CIT to test the extent to which innocent participants can be influenced by external cues or whether even with strong cues they remain unaffected. The finding that the CIT effect was not present for

innocent participants in this study is however in line with findings from previous CIT experiments where a human investigator administered the CIT (Bradley & Warfield, 1984; and Bradley & Rettinger, 1992; Elaad, 1997). Although the aim of those previous studies was not to assess any potential impact of an investigator and therefore no comparison to a non-investigator condition was made, they did indicate that innocent participants were not sensitive to the presence of an investigator.

Perhaps the most interest finding was that for guilty participants, the SCR CIT effect increased when the CIT was administered by an investigator. One potential explanation for this is based on *Motivational Impairment Effect* whereby deception performance decreases as the liar's motivation increases (DePaulo et al., 2003). It is reasonable to suspect that participants in the investigator CIT would be more motivated to conceal the crime information leading to an increased CIT effect due to the investigator's presence. However, analysis of participants' self-reported motivation to beat the CIT revealed no difference between those tested by the computer or investigator. Similarly, self-reported stress experienced during the CIT, and whether or not the participants attempted a countermeasure or not, did not differ between presentation groups, suggesting these factors cannot account for the investigator finding.

Social Facilitation research shows that the presence of others can influence behavior and performance (Zajonc, 1965) and, in the case of deception, appears to decrease lie performance (Hancock, Woodworth, & Goorha, 2010; Harrison, Hwalek, Raney & Fritz, 1978). In the CIT, a 'virtual investigator' (presented as neutral face on a computer monitor alongside the CIT images) was found to increase the CIT effect for guilty participants for heart rate, respiration and peripheral vasodilation measures, but not SCR (Ambach et al., 2012); a similar result was found using RTs in another

experiment (Varga et al., 2015). These two studies suggest that social presence, manipulated through the use of a virtual investigator, only affects parasympathetic and RT measures in the CIT. Both parasympathetic and RT measures in the CIT have been primarily linked with deceptive processes such as inhibition (Verschuere, Meijer, & De Clercq, 2011 and Suchotzki et al., 2017 respectively) and deception has in turn been shown to be affected by the presence of an investigator (Hancock, Woodworth, & Goorha, 2010). However, in another experiment where a human investigator (rather than a virtual one) was used, it was the SCR i.e. recognition measure, that was affected by an investigator and not  $\Delta$ HR (Elaad, 1997).

Nevertheless, in Elaad's (1997) study, the SCR CIT effect decreased when the CIT was administered by a human investigator knowledgeable about the crime items. In contrast, in the current study, the SCR CIT effect increased when a human investigator administered the CIT. The discrepancies between these findings may be due to one or several of the many different methodological difference between the current study and that by Elaad (1997). In comparison to the current study, the main differences in Elaad (1997) were that: i) the investigator was provided with suspicions about the guilty status of the participants; ii) the investigator only knew about two of the four crime details; iii) participants did not take the CIT for several days,  $M = 3.3$ ; iv) all 80 participants (25 guilty) were male; v) eight experienced polygraphers administered the CIT as investigator; vi) verbal stimuli was used as investigators read out each CIT item; vii) target items were included in each CIT question; viii) motivation for guilty participants was manipulated; ix) presentation of a target and the investigator's knowledge of crime items was manipulated between subjects for four CIT questions; x) finally, no comparison to a computer condition was conducted.

Response fractionation theory ([Verschuere, Meijer, & De Clercq, 2011](#)) can account for why SCR and  $\Delta$ HR in our study did not correlate. Theory and experimental evidence demonstrate that SCR, due to orienting in the CIT, is linked to suspect's recognition whereas parasympathetic measures like heart rate, reflect arousal inhibition experienced when suspects actively conceal their recognition ([klein Selle et al., 2016](#); [klein Selle, Verschuere, Kindt, Meijer, & Ben-Shakhar, 2017](#)). Therefore, the lack of investigator effect on heart rate here is surprising given we might expect participants to inhibit their recognition more to crime items when they are presented by an investigator. Although not significant, a closer examination of the  $\Delta$ HR CIT effect in [Figure 4.9](#), shows that when data were combined from both experiments, the investigator effect appears to be moving in the same direction as the SCR CIT effect i.e. an increased CIT effect for heart rate. However, this was not significant, ( $p = .127$ ) and a Bayesian t-test revealed anecdotal evidence that there was no investigator effect for  $\Delta$ HR CIT effect for guilty participants ( $BF_{01} = 1.32$ ). Potentially, the physical presence of an investigator in this study resulted in large heart rate variability (noise) masking a significant investigator effect for  $\Delta$ HR. In another study where  $\Delta$ HR was found to be affected, a virtual investigator on the computer screen was used which would likely not have produced the same heart rate response as a physical investigator ([Ambach et al., 2012](#)).

The investigator effect found for guilty participants' SCRs in this study may suggest that there is a social component to the CIT response. A simpler explanation, however, may be that the presence of the investigator increased the participant's attention to the task. Increased attention to the CIT photograph stimuli would result in retrieval/recognition of the encoded crime details when presented. Nonetheless, irrespective of the exact mechanisms involved, the current work, albeit given the

limitations discussed above suggests that investigator presence at best appears to help the CIT and at worse has no negative impact.

It is often recommended that the CIT is administered by a computer, with the suspect alone, due to concerns that an investigator may influence the suspect and thereby increase false positive rates (e.g., [Meijer, Verschuere, & Ben-Shakhar, 2011, p. 300](#)). This recommendation however had not been experimentally validated. The current study was conducted to test this concern; the initial findings tentatively suggest that the use of an investigator to administer the CIT may, in fact, be beneficial. But why use an investigator to administer a CIT? First, the current results indicate that the CIT diagnosticity increases when an investigator is used. Second, an investigator can change the questions asked in real time which is preferable in the searching CIT ([Meijer et al., 2013](#)). In searching CITs, the investigator attempts to extract information from the suspect, such as the location of a murder victim's body, and therefore each CIT question is based the result of the previous one ([Nakayama, 2002](#); [MacLaren, 2001](#); [Osugi, 2011](#); [Meijer, Bente, Ben-Shakhar & Schumacher, 2013](#)). Finally, using an investigator to administer a CIT may allow for a CIT to be administered covertly i.e. without the suspect awareness, which would likely reduce the use of countermeasures and have potential security applications. However, this would require unobtrusive and/or contactless technologies to measure a suspect's physiology. For example, a previous CIT study used hidden respiration sensors built into a chair and found that concealed information could be detected, albeit at a reduced level ([Elaad & Ben-Shakhar, 2009](#)). Other CIT studies have successfully used other contactless measures, such as pupil dilation ([Lubow & Fein, 1996](#)), facial thermography ([Pollina et al., 2006](#)) and voice stress ([Gamer, Rill, Vossel, & Gödert, 2006](#)). However, contactless physiological instruments alone are not adequate for

conducting a covert CIT. This is because using a computer administered CIT, i.e. presenting stimuli every 15-30 seconds on a monitor, makes it relatively obvious to suspects that they are undergoing a recognition test. The current findings suggest that an investigator could instead be used to administer a CIT that looks more like a structured interview where each CIT question could be mixed in with a standard investigative interview. Much further work is required to assess the extent to which this is possible and within strict ethical guidelines.

Despite the potential advantages of using a human investigator to conduct a CIT (e.g. dynamic questions, integration with other interrogation methods, increased detection of guilty suspects), more research is required before the authors would consider recommending this in the field. Indeed, using a human investigator is risky particularly for innocent suspects as the impact of a false positive reading, i.e. concluding that an otherwise innocent suspect recognises secret crime information, would be costly for all parties. This risk has been well documented in eyewitness line up research ([Perlini & Silvaggio, 2007](#); [Phillips, McAuliff, Kovera, & Cutler, 1999](#); [Douglass, Smith & Fraser-Thill, 2005](#)). Nevertheless, the findings from this study do suggest that having a human presence and conducting the CIT does impact the guilty suspect responses to crime items and therefore this possible social dimension warrants further attention.

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## CHAPTER 5

**Caught virtually lying:****Crime scenes in virtual reality help to expose suspects' concealed  
recognition****Abstract**

This study explores how virtual reality could be used in police investigations to take a suspect 'back in time' and demonstrate that they recognize a crime scene despite claiming not to. Participants committed a mock crime before being incentivized to conceal recognition of crime related details (e.g., the stolen item or crime scene). The crime scenes and objects were laser scanned, converted to photo-realistic models, and presented to suspects either in Virtual Reality (VR) or as 2D images on a computer screen. While concealing recognition of crime information, participants' heart rate and skin conductance were measured using a Concealed Information Test (CIT) to assess recognition. Detection of concealed recognition increased by over 25% when participants viewed crime items in VR compared to 2D images. Our findings suggest that revisiting crime scenes or objects in VR may enhance stimulus recognition and salience resulting in increased CIT diagnosticity.



### Introduction

Imagine if, during a police interrogation, you could ‘teleport’ a suspect back in time and demonstrate that they recognize the crime scene despite them claiming no knowledge of it. This scenario may seem farfetched, but recent advancements in virtual reality (VR) technology make this scenario possible. In this chapter, the question is asked whether VR can be used to distinguish between people who are, and people who are not, concealing recognition of specific crime information. Then the extent to which VR is a useful tool for enhancing memory retrieval is explored. To date, research on VR and memory has focused on the role of VR in enhancing encoding and learning, but VR may also be a powerful tool for memory retrieval.

In order to present crime scenes and objects to suspects without them physically being there, the crime details need to be digitally captured. Technologies for digitally capturing, documenting and visualizing scenes and objects are becoming increasingly utilized and various methods can now achieve this with exceptional precision (Puente, González-Jorge, Martínez-Sánchez & Arias, 2013). These photorealistic and geometrically accurate digital recreations are being used by architects, historians, game/film developers and forensic investigators, to name a few (Gonzalez-Jorge, Solla, Armesto & Arias, 2012; Stanco, Battiato, & Gallo, 2011; Marcin, Maciej, Robert, & Adam, 2017; and Buck, Naether, Räss, Jackowski & Thali, 2013). Digital capture technologies typically work by first capturing a cloud of points in 3-Dimensional (3D) space that represent the precise geometry of the room or object being scanned before then overlaying color detail captured from multiple photographs (Puente et al., 2013). These colored point clouds are converted into solid surfaces, resulting in digital models that can be near perfect replicas of the real-world scene or object. These models have significant advantages over photographs as they

are 1:1 scale, 360°, 3D and allow recreation of the real-world with all its imperfections and uniqueness: therefore, giving it a more ‘real’ appearance to observers.

Using VR technology, we can view digital environments in a way that recreates the feeling, scale and perspective of physically being there. Simply put, VR can be defined as “... *a very powerful and compelling computer-application by which humans interact with computer-generated environments in a way that mimics real life*” (Burdea & Coiffet, 2003). Ongoing development of VR technology has seen high-quality, yet low cost devices being tested and used in a variety of industries. Most applications are related to reviewing digital environments or products where spatial information can be more easily communicated. Other uses are in education where VR has been shown to be an effective modality for learning spatial and practical skills required in disciplines including surgery, engineering or firefighting (Häfner, Häfner & Ovtcharova, 2013).

Combining both digital capture and VR technologies allows the review of high-fidelity real-world objects and crime scenes without physical presentation (Buck et al., 2013). However, research into the possible benefits of learning and memory in VR is in its infancy. Studies assessing memory for information learnt in VR and then tested in the real world suggest that there is either no advantage of VR as a learning tool, compared to traditional methods (Voinescu & David, 2019) or that learning actually suffers in VR (Lanen & Lamers, 2018). However, little is known about memory retrieval in VR when the information is learnt naturally in the real-world. It is possible that VR facilitates memory retrieval compared to seeing learnt places or objects as pictures, but this has yet to be tested.

One classic finding in memory research is that information is more accurately retrieved when a person recalls the encoded event in the same context as it was learnt, known as *Context Reinstatement*. A seminal study demonstrated that divers who learnt words underwater recalled them better when tested underwater compared to on dry land (Godden & Baddeley, 1975). The same effect has been shown in an eyewitness context where returning participants to the physical crime scene enhanced their facial recognition performance (Smith & Vela, 1992). Context Reinstatement has also been shown to assist eyewitness accuracy in police lineups when the photograph lineups take place in the same physical or a virtual crime scene compared to contexts where they did not (such as the police station) (Guadagno, Bailenson, Beall, Dimov & Blascovich, 2005; and Bailenson, Davies, Blascovich, Beall, McCall & Guadagno, 2008).

Another factor in memory retrieval performance is the match between the modality in which the memory was encoded and later retrieved (Dewhurst & Knott, 2010). Modality Congruence, a specific type of Encoding Specificity (Tulving, & Thompson, 1973) states that memories recalled in the same modality e.g. recognizing a photograph of a scene from a set of test photographs, are stronger than if modalities mismatch e.g. recognizing a photograph of a scene from a list of text descriptions. Transfer-appropriate processing theory suggests that this is mediated by how the information is initially encoded and how it is then later retrieved (Lanen & Lamers, 2018) and is therefore enhanced when the cognitive operations carried out at encoding are reinstated at retrieval (Dewhurst & Brandt, 2007). It is thought that this is due to the reactivation of the same neural patterns established during encoding (Staudigl & Hanslmayr, 2018). This was evidenced in a study where to-be-remembered items were either visually or auditorily presented to participants who

then showed similar brain activation during the retrieval of those items when the modality matched ([Wheeler, Peterson & Buckner, 2000](#)). This process may explain the well-known Pictorial Superiority Effect in which memory retrieval is typically superior when the retrieval modality is a picture, image or photograph ([Hockley, 2008](#)).

Given the current realism of VR environments, we might expect a stronger modality congruence when memories are encoded in the real-world and then retrieved in VR compared to retrieval prompted by 2D photographs suggesting a ‘VR superiority effect’. If so, this effect could be exploited in a forensic setting where presenting a crime scene or object in VR could enhance recognition for eyewitnesses, victims and cooperative suspects compared to photographs. The next question then, is how can we measure recognition magnitude, i.e. the strength of a memory signal, and use this for uncooperative suspects who intentionally conceal their recognition of a crime? One possible method is via use of the Concealed Information Test (CIT). The CIT is a memory detection tool designed to determine whether a suspect recognizes information about a crime that only the culprit would know ([Ben-Shakhar & Elaad, 2003](#)). In CIT studies, subjects are typically instructed to carry out a simulated crime, such as stealing a specific item from a location ([Verschuere, Ben-Shakhar & Meijer, 2011](#)) (or in one case, from within a virtual environment, [Hahm et al., 2009](#)). A person without knowledge of the crime would be unable to discriminate the crime from control items. The CIT determines a suspect’s recognition of crime details via physiological responses (typically skin conductance, heart rate) to ‘crime items’ (termed probe items, such as a tablet computer stolen from a handbag) compared with their responses to non-crime related stimuli, ‘control items’ (termed irrelevant items, such as other portable electronic items or bags). Compared with

controls, crime items produce a larger physiological response, as predicted by orienting theory and arousal inhibition, which is taken as an indication of recognition of those items ([Verschuere, Ben-Shakhar & Meijer, 2011](#)). The physiology-based CIT is well established and frequently applied in real-world cases, particularly within the Japanese criminal justice system ([Osugi, 2011](#)).

In terms of application, consider, for example, a culprit who breaks into a house and finds themselves in a living room. They steal a laptop before going into a bedroom and stealing a diamond ring. The police later identify possible suspects on CCTV near the burgled property. The police could administer a CIT on all their suspects to determine who, if anybody, the culprit is. That CIT could consist of four multiple-choice questions, each with four equally plausible solutions presented to suspects sequentially. One question could be “Was this the living room broken into?” with photographs of four different living rooms: the living room from the crime and three similar control living rooms. Another question could be “What was stolen?” with text options; tablet, phone, laptop or mp3 player. The guilty suspect would show a significantly larger physiological ‘recognition response’, to the crime items e.g. the laptop than to the control items, whereas innocent suspects would show a similar response to all items. The CIT typically identifies the guilty suspect approximately 8 out of 10 times whilst correctly rejecting the innocent suspects nearly all of the time ([Ben-Shakhar & Elaad, 2003](#)). The difference in magnitude of the physiological recognition response to crime items versus control items is known as the CIT effect. This well-established CIT effect can be used as one piece of forensic evidence that indicates whether the suspect recognises details about a specific crime detail. Because the CIT is designed to test a suspect’s concealed recognition of crime details, it is often referred to as a Memory Detection technique as it measures the

strength of a person's memory signal. Note it is also considered a deception detection method because it can reveal an uncooperative suspect's concealed recognition (Granhag, Vrij, & Verschuere, 2015). It is known that the strength of memory encoding increases the magnitude of the physiological CIT effect (Gamer, Verschuere, Crombez, & Vossel, 2008) indicating enhanced recognition which is consistent with general memory research. However, can we enhance the memory retrieval process using VR and can we use the CIT to investigate the strength of a person's memory retrieval when the memory is encoded in the real-world but retrieved in VR? In testing this, we can also determine whether the VR modality is superior to using photographs and assess what impact this has on the CIT's diagnosticity.

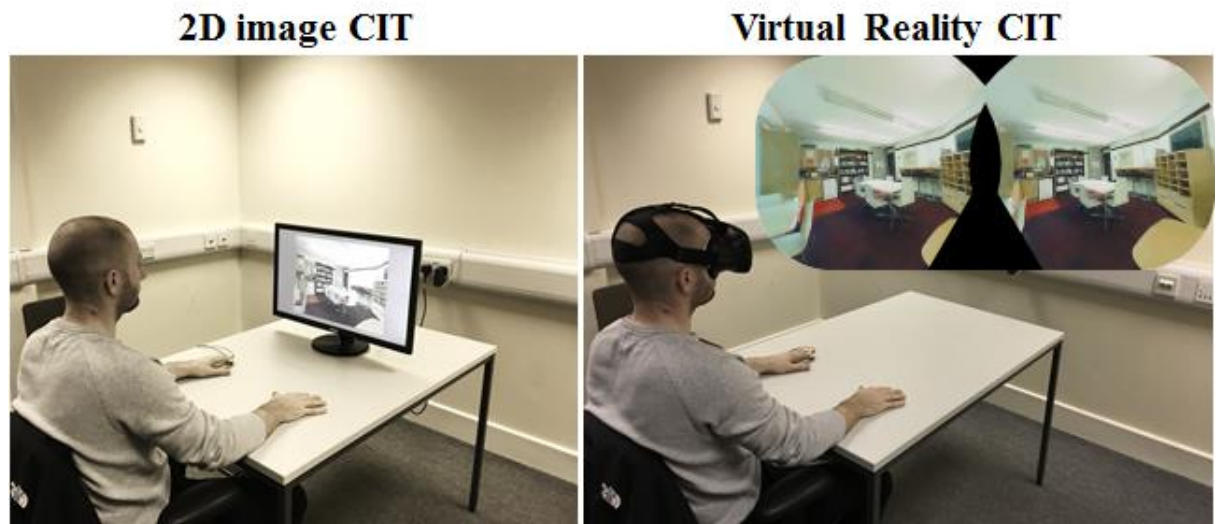
If a CIT administered in VR were tested and contrasted against a typical 2D image-based CIT, then what are we likely to find? A previous study demonstrated a positive effect of modality congruence using a P300 (an event related potential brain wave indicating recognition) CIT when comparing pictures against verbal presentation, suggesting that the physiological CIT effect found aligns broadly with memory theory (Rosenfeld, Ward, Frigo, Drapekin, & Labkovsky, 2015). Other research has demonstrated both a picture superiority effect in the P300 CIT (Zheng et al., 2019) and a modality effect (Deng, Rosenfeld, Ward & Labkovsky, 2016) when suspects attempt to conceal recognition of mock crime details. Thus, the findings above suggest that physiologically measured recognition, the CIT effect, might be larger for participants viewing crime items in VR compared to viewing 2D images due to VR-driven increased modality congruence.

Feature matching theory conceptualizes the above memory models whilst offering a specific framework for understanding physiological orienting and its

relationship to recognition intensity. It has been demonstrated that the physiological response caused by orienting is monotonically related to the similarity between the encoded and test stimuli (Ben-Shakhar & Gati, 1987). As the number of overlapping features between the encoded and test image increases, so does the magnitude of the physiological CIT effect. This has important implications for the CIT as it suggests that the CIT effect should increase as the similarity between the presented crime item and: i) the actual crime memory increases, and ii) control item decreases (Marchand, Inglis-Assaff & Lefebvre, 2013). Hence, feature matching theory predicts that, compared to 2D image stimuli, VR presentation of real-world digital recreations will increase the physiological CIT effect by increasing responses to crime items and decreasing responses to control items. This is due to the increased number of features available, e.g. scale and 3D depth, for the suspect to correctly match the crime item to a memory of the real-world. Thus, both memory recognition research and CIT theory suggest that there should be a physiologically measurable benefit to a person's recognition of crime details encoded in the real-world and retrieved in VR when compared to 2D images.

This hypothesis was tested by having sixty-four 'guilty' participants commit a mock crime before being incentivized to conceal recognition of details relating to that crime - another sixty-four 'innocent' participants knew nothing about the crime. The crime scenes and objects were laser scanned and converted to photo-realistic models. Half of the innocent and guilty suspects viewed these models in a VR-CIT whilst the remaining half saw them in a 2D image-based CIT (Figure 5.1). Suspects' heart rate and skin conductance response (SCRs) were measured for both crime and control items to determine the recognition memory signal and consequently the CIT diagnosticity. The findings will indicate: i) whether memory retrieval is superior in

VR compared to 2D images, and ii) whether a VR-CIT offers increased diagnosticity as a forensic memory detection test. This study was approved by the departmental ethics committee at the author's institution.



*Figure 5.1. A participant viewing the crime scene; as 2D images on a monitor (Left), or within a 3D, 1:1 scale, head-tracked virtual reality environment (Right).*



## Method

### Participants

According to a meta-analytic review, the CIT effect between innocent and guilty is typically large ( $d = 1.55$ ), indicating that 8 people per group is sufficient for finding a main CIT effect (Ben-Shakhar & Elaad, 2003). Estimating the effect size of testing modality and feature matching was more problematic given no previous studies had compared physiological recognition for VR against 2D photographs. One study revealed a large effect for modality congruence between picture and verbal stimuli using the P300 CIT (Rosenfeld et al., 2015). In providing evidence for their feature matching theory, Ben-Shakhar and Gati (1987) found large modality effects with groups of 30 participants. Based on these findings it was estimated that there would be a large modality effect size (Cohen, 1988). A power analysis using G\*Power (Faul, Erdfelder, Lang, & Buchner, 2007), assuming a large effect size of  $d = 0.8$ , and  $\alpha = 0.05$  for a single group, suggested a minimum sample size of 23 participants would be sufficient for a power of 0.95. Because up to 25% of participants could be skin conductance non-responders (Venables & Mitchell, 1996) the sample was increased to 32 per each of the four groups for a total sample size of 128.

One-hundred and twenty-eight adults (59% women, 18 - 46 years,  $mean = 21$ ,  $SD = 4.1$ ) were recruited via a university online participant panel at the authors' institution. Participants received £4 payment for participating in the 30-minute testing session and the opportunity to receive their 'lie detection score'. Participants were incentivized with the chance to win a £25 Amazon voucher if they obtained the lowest score. Participants were equally split and randomly allocated to one of four

experimental conditions: Guilty with a VR-CIT, innocent with a VR-CIT, guilty with a 2D image CIT and innocent with a 2D image CIT.

### **Materials**

**The CIT.** Participants in the guilty condition carried out a mock crime in which they entered an office, identified an unattended handbag and stole a tablet computer before handing it over to an ‘accomplice’ in the department common room. The four key crime details used in the CIT were the office, handbag, tablet and common room. The CIT therefore consisted of four questions/blocks each containing one crime item and three control items (Figure 5.2). CIT blocks were presented in a random order and each began with a question presented for 10s followed by a 1s blank. The four items were then presented sequentially for 5s followed by a 10s blank (Figure 5.3). Three seconds prior to each item (excluding the first item), a subsection of the question was presented as a reminder (e.g., “Was this the bag?”). The first item presented in each CIT question was a buffer; a control item used to absorb the initial orienting to that item group. The four CIT blocks were then randomized again and repeated resulting in participants seeing eight CIT blocks in total. Participants were instructed to respond verbally with ‘no’ or ‘don’t know’ in response to each item.

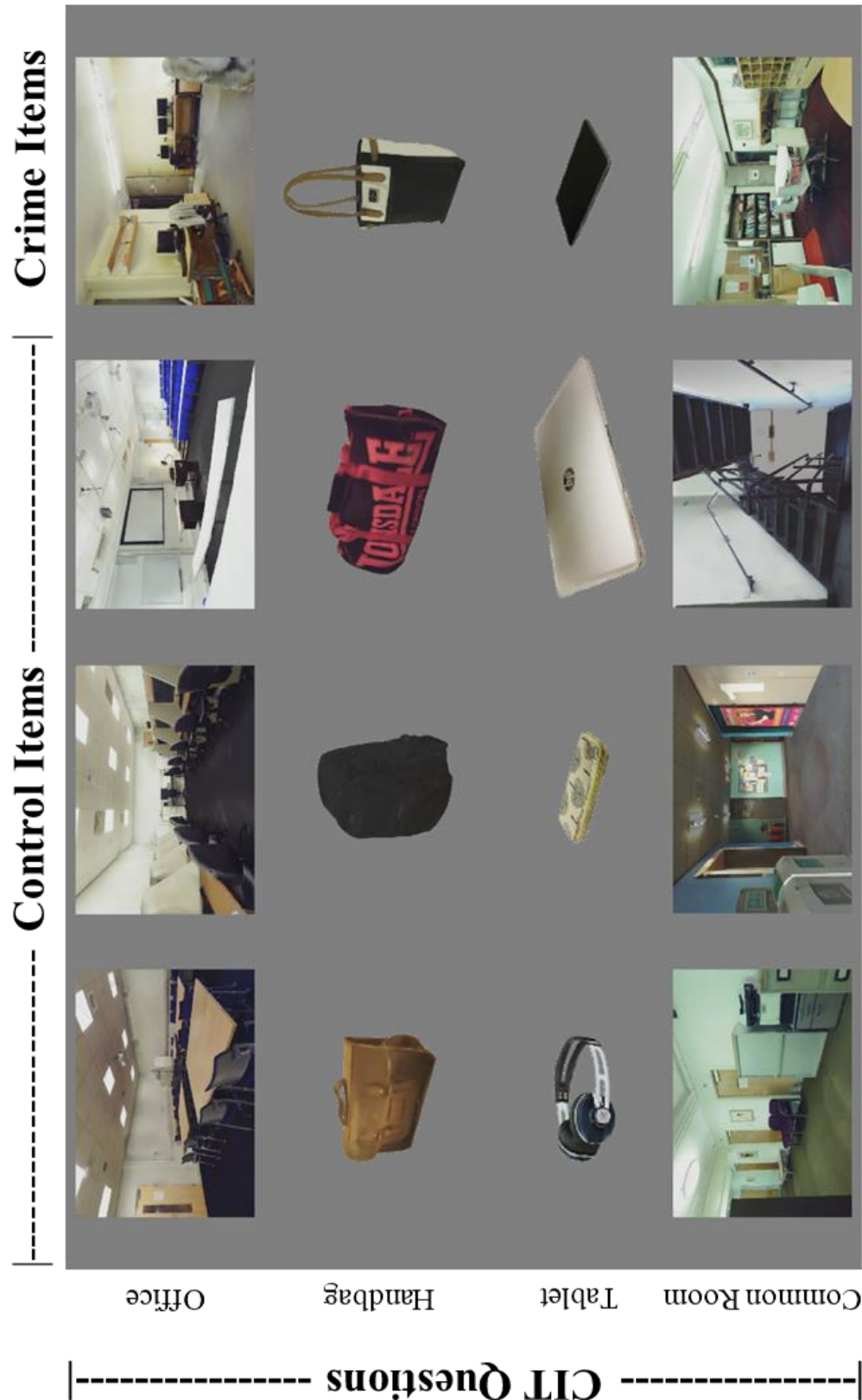


Figure 5.2. The four CITs with 2D images of the VR models used in this study with crime items on the right.

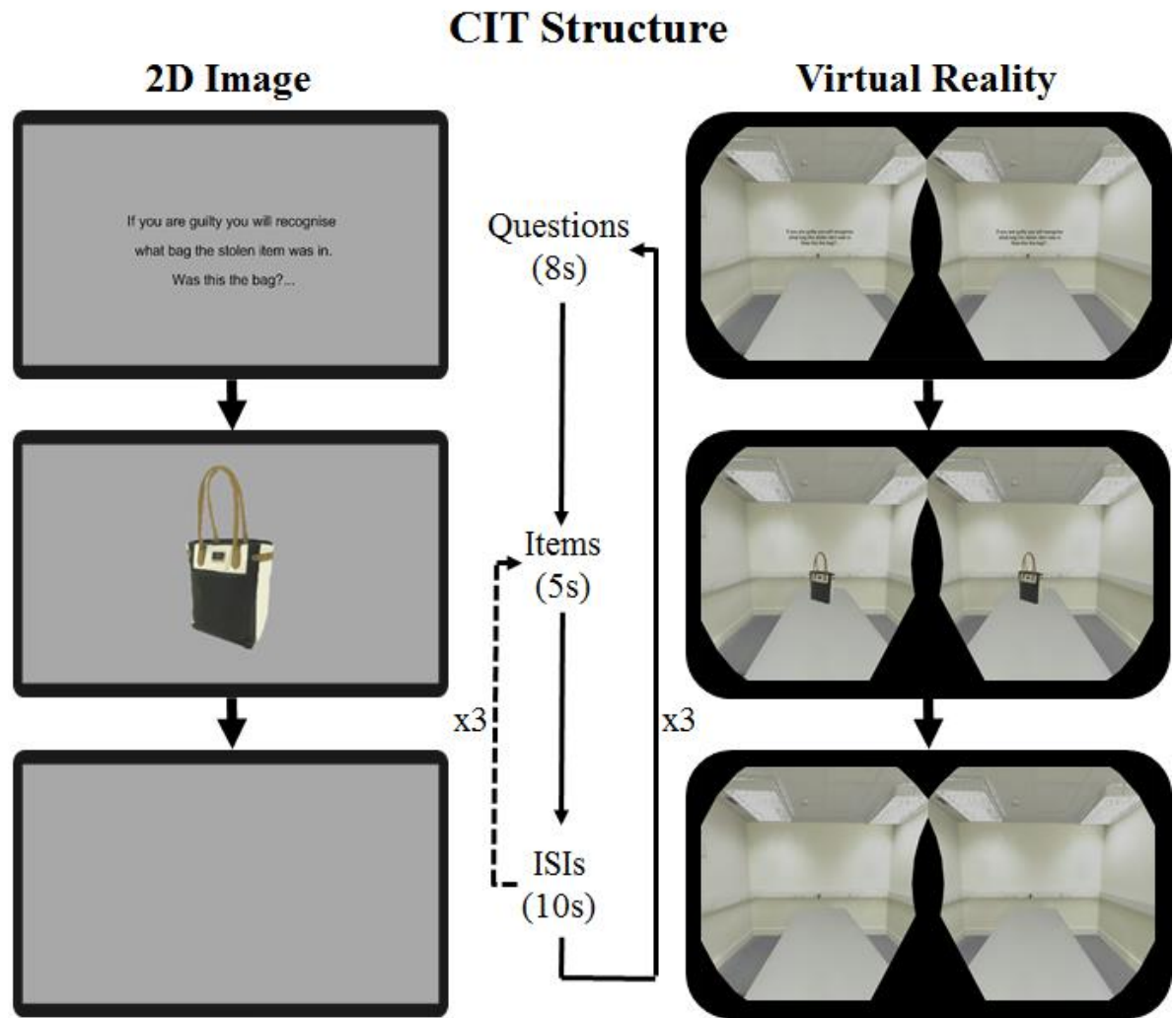
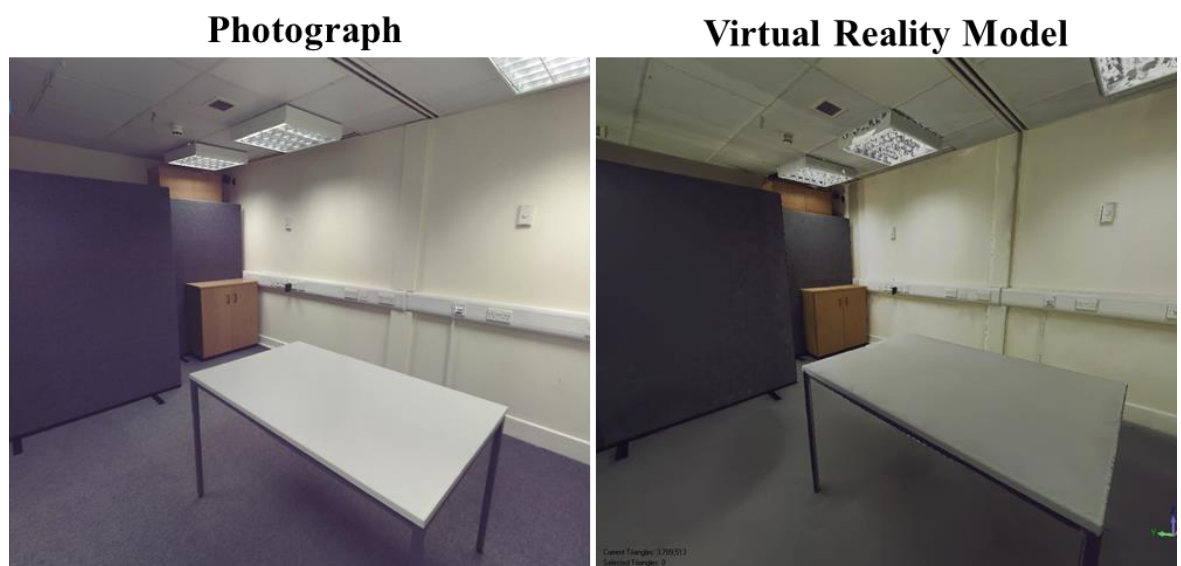


Figure 5.3. The CIT structure (centre) for both the 2D image (left) and Virtual Reality (right) CITs. From the top, the CIT begins with the question (8s) followed by presentation of one of the three control items (5s), followed by removal of that item (10s). Another item is then presented, and this section is repeated until all four items, three control and one crime, have been presented. The next CIT question is presented, and the process is repeated until all four CITs have been presented. This is then repeated once to complete the main testing phase.

**Virtual Reality Stimuli.** A FARO Focus 3D X330 Laser Scanner was used to capture multiple colored point cloud models of 11 scenes. The scanning parameters were: Resolution = 8192 pt/360° with point cloud size = 7984 × 3414 (i.e. 27 million points) and Quality = 4x resulting in 9-minute scans. The scenes were cleared of

clutter with window blinds drawn and available indoor lighting switched on. Objects were captured using a FARO Freestyle 3D handheld scanner which is designed to scan objects with a resolution  $<1.5\text{mm}$ . The resulting models were photorealistic 1:1 scale, 360 degree and 3D detailed copies of real scenes and objects (Figure 5.4). The VR condition contained motion from changes in the participant's viewpoint as a result of tracked head movements, however, none of the stimuli contained independent object motion. For maximal control between the VR and 2D image condition, 1920 x 1080 screenshots of the VR models were taken from the view of the participant in VR to act as the stimuli for the 2D image CIT condition. The virtual reality models used in this research are available on request from the authors.



*Figure 5.4. Photograph of the lab where participants underwent the CIT (Left). Photorealistic virtual model of the lab used as a base for participants in the VR condition (Right).*

### Physiological Data

Electrodermal activity (EDA) and heart rate were recorded using a MP36R data acquisition unit (*Biopac Systems Inc*) with pre-gelled disposable Ag/AgCL electrodes (EL507 and EL501 for EDA and heart rate respectively). EDA electrodes

were attached to the distal phalanges of the first and middle finger of the non-dominant hand with EDA signals sampled at 1000Hz at  $\times 2000$  gain and filtered using a 66.5Hz low pass filter. For heart rate, Electrocardiogram (ECG) electrodes were placed in a standard Einthoven Lead I Configuration: one placed on the ventral side of the dominant wrist, another on the non-dominant lateral aspect of the distal fibula, and the third electrode utilising the EDA ground electrode placed on a non-dominant distal phalange. ECG signals were sampled at 1000Hz at  $\times 1000$  gain, with a 66.5Hz low pass filter and a 0.5Hz high pass filter. Electrodes were attached for approximately 5 minutes before data collection. A webcam recorded participants from a side view to allow noise removal if participants made substantial movements.

Skin conductance responses were defined as the difference in absolute magnitude of tonic skin conductance peaks and their respective peak onsets. Skin conductance peaks were identified using an *AcqKnowledge* v4.2 propriety algorithm (Kim, Bang & Kim, 2004), with parameters ensuring peak onsets were within a 0.5-5s window following stimulus presentation and maximum peaks within 10s (Gamer, 2011) - this output was manually checked for errors. For heart rate, an *AcqKnowledge*'s propriety Heart Rate algorithm was used on the ECG signal to detect R peaks, classify the time interval between them, and automatically filter artefacts. The R-R interval was then converted to instantaneous heart rate (beats per minute) before baseline-correction via subtraction of the 3s mean heart rate prior to stimulus onset. The average baseline-corrected heart rate was calculated between stimulus onset and 15s after, resulting in the mean heart rate change measure. This measure has been shown to outperform other measures of heart rate change when analysing physiological data from the CIT (Gamer, 2011). Due to individual differences in physiological responsiveness, within-subjects standardised scores (z-

scores) were calculated for each individual measure (Ben-Shakhar, 1985). Responses to mean normalised physiological responses to crime items were used to indicate the CIT effect (Meijer, Selle, Elber & Ben-Shakhar, 2014).

We removed data from a trial if there was excessive movement within a 0-2s window prior to individual stimulus onsets (klein Selle, Verschuere, Kindt, Meijer, & Ben-Shakhar, 2016). Signals were removed if the sensors became dislocated or dislodged during the experiment. Participants with a standard deviation of raw SCR responses below  $0.01\mu\text{S}$  were considered skin conductance non-responders and the EDA data were removed from analysis (klein Selle et al., 2016). Finally, the first trial in each CIT block, always a control item, was removed prior to analysis as its sole role is to absorb the initial orienting to that CIT item group. In total five participants met our criteria for SCR non-responders and their data were excluded from the SCR analysis. Six participants' heart rate data were excluded from the analysis due to dislodged sensors; one guilty participant in the 2D image and three in the VR condition, and two innocent participants in the 2D image condition. Out of 4096 trials, 21 (0.5%) were removed from analysis due to large movement artifacts. All raw physiological data can be found in the supplementary materials.

### **Procedure**

Participants were provided with an overview of the study procedure (but not told about the different conditions) including their right to withdraw, given the opportunity to ask any questions, and invited to provide consent and demographic information (age and gender).

**Mock Crime.** Participants assigned “guilty” carried out a mock crime. The experimenter<sup>1</sup> made it clear that it was not a real crime, but participants should try to imagine it was and therefore not get caught. Participants were asked to imagine that they were partners in crime with the experimenter, and that the experimenter had identified an unattended bag in an office that had a tablet computer poking out the front pocket. Participants were asked to discretely steal the computer before returning it to their accomplice in the common room who could then sell it for money. While viewing a floor plan of the building with photographs of the key details, participants were given the following instructions: i) Head left from the start point [highlighted on the floor plan] and find the open office H122 [highlighted on the floor plan]; ii) Knock on the door and tell the person inside that: “Danni has asked that I wait for her in here”; iii) Sit at the desk in the corner with the handbag next to it for about a minute; iv) Steal the tablet from the handbag and leave; and v) Wait for me in the psychology common room - I will be a few minutes) [highlighted on the floor plan]. Participants were not told that the people in the office knew about the experiment (which they did but were asked to ignore the participants' activities). However, if participants did directly ask whether people in the office knew about the experiment, the experimenter confirmed that they did (this happened twice). Participants typically completed the mock crime in approximately 3 minutes. Participants assigned “innocent” moved immediately to the CIT phase.

**Instructions.** Following the mock crime—or following the consent phase for those in the innocent group—participants were asked to imagine that they had been

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<sup>1</sup> The procedure prevented the experimenter from being blind to both the suspect and modality conditions. This was because the mock crime condition required additional instructions and management by the experimenter and the requirement to apply the head-tracked VR headset in the VR condition.



contacted by the authorities informing them that they were now a suspect in a recent crime and therefore would undertake a lie detection test. They were reminded to try to appear as innocent as possible and therefore to deny any knowledge of the crime. The EDA and ECG electrodes were then applied as described in the Physiological Data section.

**VR Setup.** Participants in the VR condition put on and adjusted the VR headset for a comfortable fit. The default pupil distance was set as 62mm, but participants could change it in the preview if needed (no participants did). Participants were advised that they could remove the headset at any point if they felt any form of motion sickness or fatigue or for any other reason (none did). Participants were told that one potential method that could be used to fool the test would be to simply close their eyes. The experimenter instructed participants not to do this because in the real-world eye trackers could be installed in the headset to detect when people were intentionally closing their eyes. Participants were asked to remain seated during the CIT and to keep their head relatively still and forward facing. A similar instruction was given to participants in the 2D image condition.

**Stimulus Preview.** Previewing all items in the CIT prior to testing is recommended to reduce the novelty for each stimulus preventing a confounding orienting signal ([Verschuere & Crombez, 2008](#)). It also allowed the experimenter to visually explain the CIT procedure as well as familiarize participants with the task. In the preview, participants saw each CIT question followed by the four stimuli in a random order, either all in VR or all as 2D images depending on the condition, that accompanied that question. The stimuli lasted for 5s with no inter-stimulus interval. Following the preview, participants could ask any questions before the main CIT

commenced. This phase was particularly useful for participants who had not previously used a VR headset before or experienced a virtual environment.

**The CIT.** Participants were reminded to appear as innocent as possible and deny all knowledge of the crime. They were also reminded that they were being filmed and that they should try to remain as still as possible. During the CIT the experimenter sat quietly behind a screen out view of the participant. The participants then underwent the CIT as described above.

**Post-CIT Questionnaire.** Participants were given a paper-based questionnaire consisting of multiple-choice questions to check that they had remembered the crime items. Participants were also asked to rate their motivation to beat the CIT on a 6-point scale (1 = *no motivation*, 6 = *highly motivated*), their stress during the mock crime and CIT on a 6-point scale (1 = *no stress* to 6 = *highly stressed*), how immersive they found the mock crime scenario and how well they believed they appeared innocent on a 6-point scale (1 = *not immersive* 6 = *highly immersive*). Participants were also asked to provide an open answer to the question: “*Did you do anything to try and fool the polygraph test? If you did or didn’t please bullet point below – either case is fine.*” Finally, participants were debriefed.

## Results

### Skin Conductance Responses

The key finding was that SCRs to crime items were larger for participants undertaking the VR-CIT compared to the 2D image equivalent, but only for guilty participants and not innocent participants. Mean normalized crime item SCRs were analyzed using a 2 (Modality: VR vs. 2D) x 2 (Suspect: Guilty vs. Innocent) ANOVA (Figure 5.5). This revealed significant main effects of Suspect,  $F(1, 119) = 49.3$ ,  $p < .001$ ,  $MSE = 3.22$ ,  $\eta_p^2 = .293$ , SCRs were larger for guilty participants than for innocent suspects. There was a marginal difference for Modality,  $F(1, 119) = 3.69$ ,  $MSE = .24$ ,  $p = .057$ ,  $\eta_p^2 = .030$ , SCRs to crime items were marginally larger in the VR condition than in the 2D condition. There were significant two-way interactions between: Modality and Suspect,  $F(1, 119) = 7.2$ ,  $MSE = .471$ ,  $p = .008$ ,  $\eta_p^2 = .057$ , SCRs to crime items were larger for participants in the VR-CIT compared to the 2D image condition but only for guilty participants. A follow-up t-test revealed that for Guilty participants, SCRs to crime items were larger in VR compared to the 2D image condition suggesting that VR enhanced guilty suspects' recognition strength of the crime related items,  $t(62) = 3.26$ ,  $p = .002$ ,  $d = .813$  ( $MD = .213$ ). There was no effect of Modality for innocent participants,  $t(57) = .544$ ,  $p = .589$ ,  $d = .130$  ( $MD = .035$ ). Finally, crime item SCRs were larger for Guilty participant compared to Innocent in both the VR,  $t(61) = 6.98$ ,  $p < .001$ ,  $d = 1.75$  ( $MD = .448$ ), and 2D image condition,  $t(58) = 3.02$ ,  $p = .004$ ,  $d = .798$  ( $MD = .200$ ).

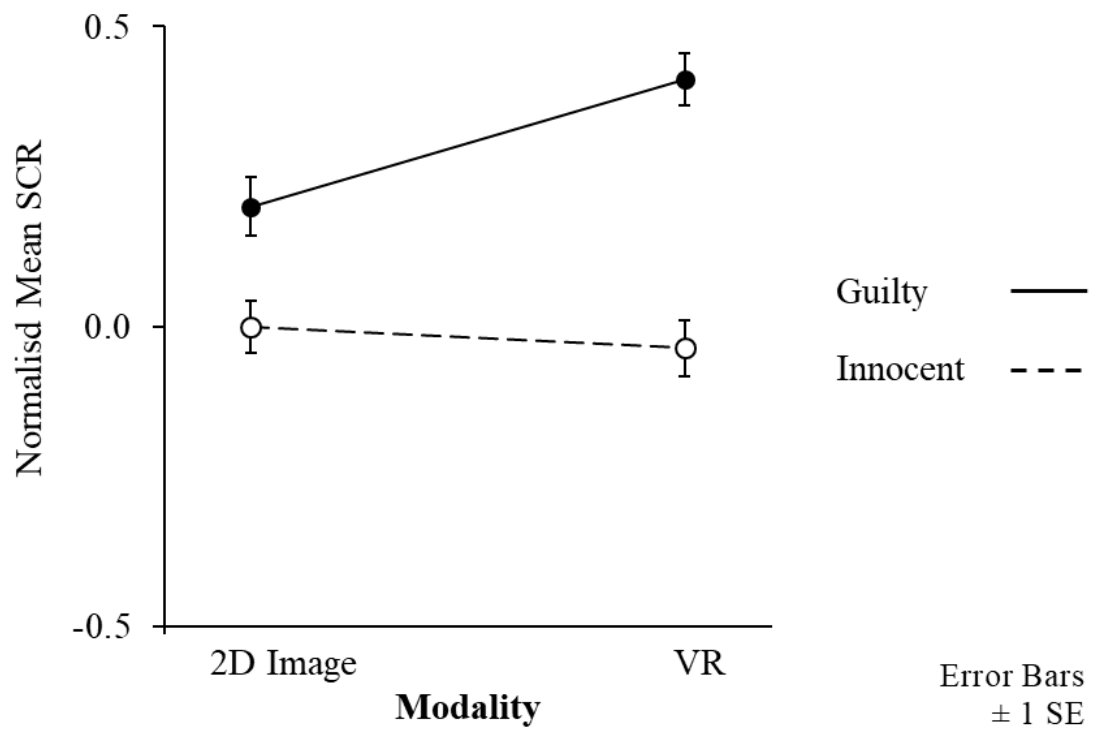


Figure 5.5. Mean normalized SCR as a function of Modality and Suspect.

### Heart Rate Change

The  $\Delta$ HR CIT effect was larger for guilty participants, but this was not affected by the modality of the CIT. Mean normalized crime item  $\Delta$ HR values were analyzed using a 2 (Modality: VR vs. 2D) x 2 (Suspect: Guilty vs. Innocent) ANOVA (Figure 6). This revealed significant main effect of Suspect,  $F(1, 118) = 9.9$ ,  $MSE = .994$ ,  $p = .002$ ,  $\eta_p^2 = .077$ , heart rate decelerated more for guilty participants than innocent participants. However, there was no Modality effect,  $F(1, 118) = .001$ ,  $MSE = 0$ ,  $p = .980$ ,  $\eta_p^2 = 0$ , or interaction between Suspect and Modality,  $F(1, 118) = .079$ ,  $MSE = .008$ ,  $p = .780$ ,  $\eta_p^2 = .001$ .

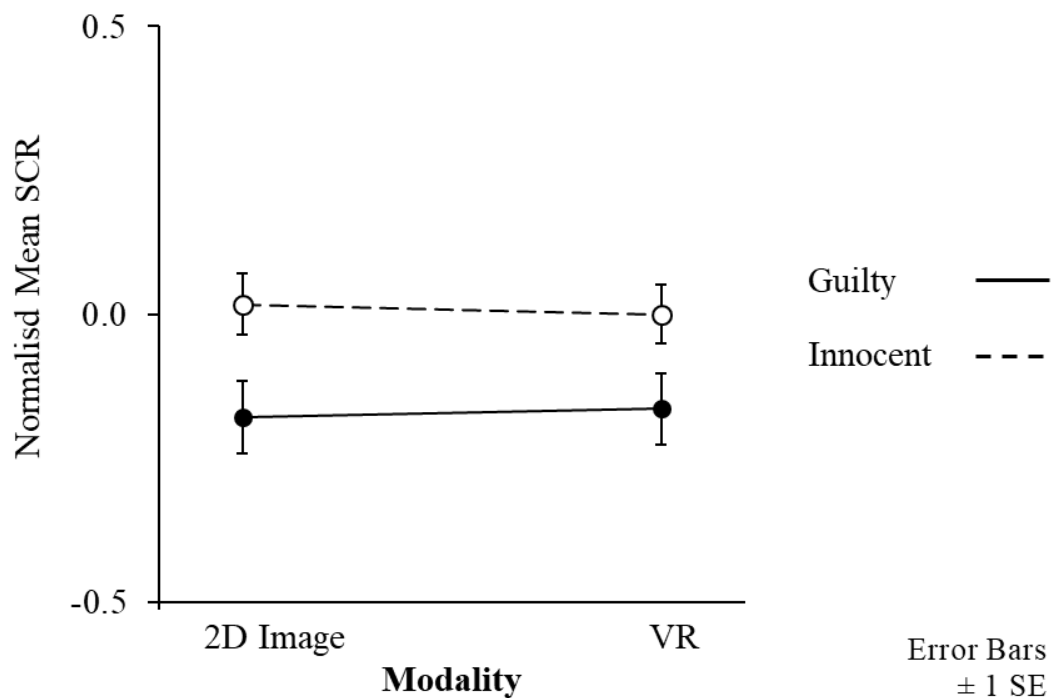


Figure 5.6. Mean normalized heart rate change as a function of Modality and Suspect.

### Signal Detection Analysis

To assess the efficiency of deception detection for both modalities used in this study, a signal detection analysis was conducted to determine the degree of separation between the guilty and innocent participants. A Receiver Operator Curve (ROC) was generated using the SCR data for both the guilty and innocent groups in the VR and 2D image conditions. As shown in Figure 7, the curves are closer to the upper left-hand corner of the ROC which indicates high overall accuracy (Zweig & Campbell, 1993). The area under this curve (*AUC*) allows an objective measure of diagnosticity; the accuracy trade-off between the test sensitivity and specificity. An *AUC* of 0.5 suggests no discrimination, 0.7-0.8 is considered fair, 0.8-0.9 is excellent, and 0.9+ is outstanding (Hosmer Jr, Lemeshow, & Sturdivant, 2013). In the VR condition the SCR CIT effect's *AUC* was .901 (0.822 - 0.981,  $CI^{95\%}$ ), indicating an excellent diagnostic test with a large guilty-innocent effect size,  $d = 1.75$ . In the 2D image condition the SCR CIT effect's *AUC* was .709 (0.577 - 0.840,  $CI^{95\%}$ ) indicating a fair diagnostic test and the effect size was large ( $d = .798$ ). The detection rate in VR was significantly better than the 2D image condition,  $AUC_{diff} = .192$ ,  $SE = .077$ ,  $z = 2.47$ ,  $p = .007$ . Note, no effect of Modality was revealed for  $\Delta HR$  therefore a combined *AUC* = .664 (0.567 - 0.761,  $CI^{95\%}$ ), and ROC (Figure 5.7) were computed which indicated a limited diagnosticity with a medium guilty-innocent effect size  $d = .723$ .

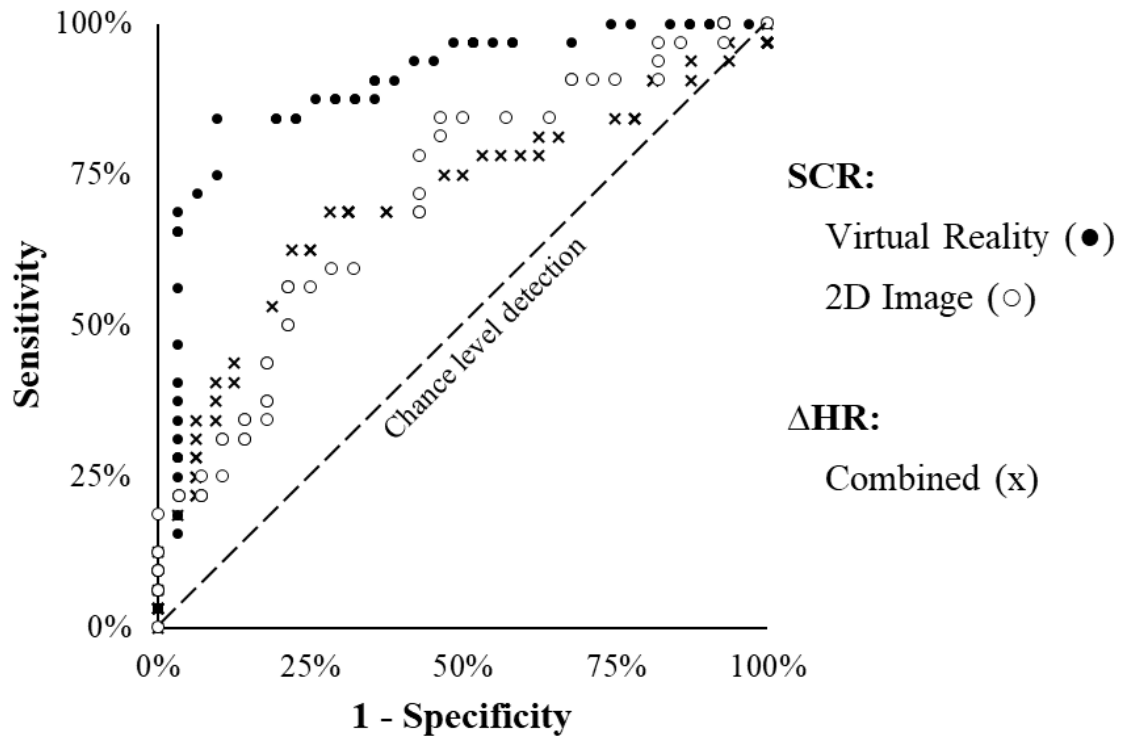


Figure 5.7. Signal detection curve (ROC) showing the detection sensitivity and specificity between guilty and innocent participants who either took the CIT in VR or on a 2D computer monitor.

### Post-CIT Questionnaire

No additional factors measured in the Post-CIT Questionnaire significantly differed across between groups, suggesting that it was unlikely that they influenced the above findings. All guilty participants correctly recalled all crime items whereas innocent participants performed at chance level in the memory test,  $t(63) = 1.1$ ,  $p = .28$ ,  $MD = .125$ . Overall participants' self-reported motivation was moderate,  $M = 4.9$ ,  $SD = 0.9$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>). Mean self-reported motivation was analysed using a 2 (Modality: VR vs. 2D)  $\times$  2 (Suspect: Guilty vs. Innocent) ANOVA. This revealed a significant main effect of Suspect,  $F(1, 127) = 14.1$ ,  $MSE = 9.6$ ,  $p < .001$ ,  $\eta_p^2 = .974$ , with guilty participants self-reporting as more motivated ( $M = 5.2$ ,  $SD = 0.7$ ) than innocent participants ( $M = 4.7$ ,  $SD = 0.7$ ). However, there was no

significant interaction between Modality and Suspect,  $F(1, 127) = .56$ ,  $MSE = .38$ ,  $p = .455$ ,  $\eta_p^2 \approx .0$ , and no main effect of Modality,  $F(1, 127) = .01$ ,  $MSE = 0$ ,  $p = .915$ ,  $\eta_p^2 \approx 0$ .

Overall, participants' self-reported stress during the mock crime was neutral,  $M = 3.2$ ,  $SD = 1.6$  (range = 1<sub>no stress</sub> to 6<sub>highly stressed</sub>), with no significant difference between the 2D image or VR condition,  $t(62) = .54$ ,  $p = .588$ ,  $MD = 2.19$ . Overall, participants' self-reported stress during the CIT was low,  $M = 2.5$ ,  $SD = 1.3$  (range = 1<sub>no stress</sub> to 6<sub>highly stressed</sub>). Mean self-reported stress during the CIT was analysed using a 2 (Modality: VR vs. 2D)  $\times$  2 (Suspect: Guilty vs. Innocent) ANOVA. This revealed a significant main effect of Suspect,  $F(1, 127) = 17.2$ ,  $MSE = 27.2$ ,  $p < .001$ ,  $\eta_p^2 = .122$ , with guilty participants reporting more stress ( $M = 3.0$ ,  $SD = 1.4$ ) than innocent participants ( $M = 2.0$ ,  $SD = 1.1$ ). There was no significant interaction between Modality and Suspect,  $F(1, 127) = 1.1$ ,  $MSE = 1.76$ ,  $p = .293$ ,  $\eta_p^2 = .009$  and no main effect of Modality,  $F(1, 127) = .84$ ,  $MSE = 1.32$ ,  $p = .362$ ,  $\eta_p^2 = .007$ .

In the guilty group, 50% of participants indicated that they had used a VR headset at least once before, versus 38% of the innocent, this was not significant,  $\chi^2(1, N = 64) = 1.02$ ,  $p = .313$ . Twenty-six participants (21%), all from the guilty condition, reported using some form of countermeasure to fool the test: Nine reported trying to imagine a different image when the crime item appeared; sixteen reported trying to control or relax their breathing; and one tried to answer verbally "no" in the same way. The difference between the number of guilty participants attempting countermeasures in either of the Modality conditions, 16%, was non-significant,  $\chi^2(1, N = 64) = 1.04$ ,  $p = .309$ .



### Discussion

These findings show that skin conductance responses, taken to indicate recognition, are enhanced when crime scenes and objects, initially encoded in the real-world, are presented as VR models as opposed to 2D images. This is important to researchers and practitioners because VR may improve the diagnosticity of the CIT as a forensic memory test. To the authors knowledge, this study is the first to show that the SCR CIT effect is larger for guilty suspects, but not innocent suspect, who undertake a VR-CIT compared to a 2D image equivalent. It's proposed that these findings indicate recognition intensity increases for scenes and objects viewed in VR compared to 2D images.

These findings fit with well-established theories of memory. Modality congruence predicts that memories retrieved in the same or similar modality as they were encoded are stronger than if the modalities mismatch ([Dewhurst & Knott, 2010](#)). The VR stimuli likely produced a closer match to the real-world in which the memory was encoded, thereby increasing the recognition signal. Transfer-appropriate processing theory suggests that recognition increases when cognitive processes used during encoding are reinstated at retrieval ([Dewhurst & Brandt, 2007](#); [Lanen & Lamers, 2018](#)). The VR models in this study closely mirrored the real-world, which likely activated systems used to process and encode the real-world equivalents. Finally, feature matching theory predicts that as the number of matching features between the test stimulus (VR crime scene) and the encoded memory (actual crime scene) increase, so too does the physiological orienting magnitude ([Ben-Shakhar & Gati, 1987](#)). An increase in SCR to crime items was observed which may be due to an increased feature overlap between the real-world crime details and the VR models resulting in enhanced recognition strength for the crime items.

The proposal for these findings is that the larger SCRs to crime items in the VR condition, represents greater recognition strength. This is due to the increased feature match (size, depth etc) between the stimuli presented in VR and the participant's memory of the stimulus (Ben-Shakhar & Gati, 1987; Stelmack, Plouffe, & Winogron, 1983; Marchand, Inglis-Assaff, & Lefebvre, 2013). However, of note, there was no reliable difference between recognition in the VR versus 2D conditions in the explicit memory test presented after the CIT. Indeed, all guilty participants explicitly recognized all crime related items when given a recognition test following the CIT. It is possible that the explicit test was simply not sensitive enough to detect differences that were nonetheless detectable by the physiological SCR measure.

An alternative explanation for our findings, however, is that the crime stimuli were more salient when presented within VR than as 2D images. Previous work (e.g., Kleinberg and Verschuere, 2015, see also Klein Selle, Verschuere, Kindt, Meijer, & Ben-Shakhar, 2017; Meijer, Verschuere & Ben-Shakhar, 2011; Jokinen, Santtila, Ravaja & Puttonen, 2006) has shown that items with higher personal salience (e.g., country of origin or birthday) produce a larger reaction time CIT effect than less personally salient stimuli (e.g., favorite color or animal). It is possible that the VR presentation differentially increased the salience of the crime items based on their personal relevance (e.g., related to the memory of a crime) whilst having little impact on the less salient irrelevant items. By this account a larger CIT effect (physiological orienting) would occur without a change in explicit memory – as was found in our study. Although the present data do not allow us to differentiate between these alternatives' explanations, this would be a useful goal for future research.

In contrast to the SCR findings, there was no effect of modality (VR/2D-image) on heart rate indicating that only one of our hypotheses was confirmed.

Response fractionation theory attempts to explain why SCR and heart rate (along with other parasympathetic measures) do not always correlate ([Verschuere, Meijer, & De Clercq, 2011](#)). This theory postulates that while SCRs are related to recognition via orienting processes, heart rate change reflects arousal inhibition experienced when actively concealing and suppressing recognition ([klein Selle et al., 2016](#); [klein Selle et al., 2017](#); [klein Selle, Verschuere, & Ben-Shakhar, 2018](#)). One might expect that if VR facilitates a stronger recognition of the criminal activity and associated emotional arousal, then a greater amount of inhibition would be required by the guilty suspect – this was not found. One possibility for this is that inhibition might already have been at ceiling in the 2D image condition leaving no additional inhibition to be measured within the VR condition. Further exploration of this fractionation finding would be beneficial.

Motivation to beat the CIT ([Ben-Shakhar & Elaad, 2003](#)), stress during encoding and retrieval ([Verschuere, Ben-Shakhar, & Meijer, 2011](#)) and attention during retrieval can influence the CIT. However, none of these factors appear to account for our findings. Specifically, there were no significant differences in ratings of motivation or stress between modality conditions. There was also no difference in previous VR experience between our modality conditions. Indeed, we attempted to mitigate against both the novelty of the VR and the novelty of each scene and object stimulus by having participants preview all questions and items before the CIT ([Verschuere & Crombez, 2008](#)). A noteworthy issue with our study was that, compared to the innocent group, guilty participants took part in a longer (approximately 3 minutes) and more complex procedure. Although this is unlikely to have impacted our VR effect, it is of course possible that it may have interfered with the suspect effect and interaction. Further work could test this by having innocent

participants carry out a similarly complex and timely task that does not relate to the mock crime.

Although not part of the planned analysis, an investigation was conducted to determine whether there was any impact on whether the CIT stimuli were Scenes (Office and Common Room) or Objects (Handbag and Tablet) on physiological responses. This could have modulated the results as viewing scenes in VR compared with 2D images is different both quantitatively (size and scale) and qualitatively (being inside the scene, the level of immersion). In contrast the difference between VR and 2D image presentation is smaller for individual objects. Additionally, scene and object images are processed differently within the brain (Oliva & Torralba, 2006). Nevertheless, including this factor in this analysis revealed no significant interactions or main effects of stimulus type (all  $p$ s > .05) thus providing no evidence that recognition strength was modulated by whether the stimulus was an object or scene.

The typical diagnosticity in mock crime paradigms with SCR is approximately  $AUC = 0.84$ , (0.83 - 0.87,  $CI^{95\%}$ ) (Meijer et al., 2014). Although our VR-CIT AUC is relatively high ( $AUC = 0.901$ ), the diagnosticity for our 2D image condition is relatively low ( $AUC = .710$ ). This could be due to the smaller number of control items (three instead of the four typically used) and the smaller number of CIT questions (four instead of five) used in our study. Notably, the SCR diagnosticity for our 2D-image condition was within the 95% confidence range for mock crime studies with only four CIT questions ( $AUC_{4\text{ CITs}} = 0.81$ , 0.71 - 0.88  $CI^{95\%}$ , Meijer et al., 2014).

The benefits of using VR to increase ecological validity while maintaining experimental control is well documented (Krokos, Plaisant, & Varshney, 2019;

Parsons, 2015; Reggente et al., 2018) and other work demonstrates possible clinical applications (Negut, Matu, Sava, & David, 2016). Creating photo-realistic VR models from real-world scenes however, requires specialist technology, time and expertise, and presents complications such as how to deal with a sky in outdoor scenes or how-to laser scan reflective surfaces. Nevertheless, the use of digitally captured objects and scenes is increasing across a range of industries, including forensic crime scene documentation<sup>2</sup>, and as the technology validation cycle continues, the more accessible and user friendly these technologies will become.

Currently in lab-based and applied CITs, images or words are presented to suspects to elicit physiological recognition responses. Models of memory suggest that returning suspects to the actual real-world crime scene would elicit the greatest recognition response. However, this would not be possible in a CIT as many stimuli are required to be presented sequentially in a tightly controlled and timed manner; additionally, crime scenes typically change over time which would weaken their match with the culprit's memory. Laser scanning the crime scenes and/or objects and presenting them to suspects in VR is the next best option. This approach means that the suspect can be visually 'taken back' to the crime scene without physically leaving the interview room. As more and more crime scenes and objects are digitally scanned, these virtual scenes and objects could potentially form a database of CIT stimuli ready for use as control items within a VR-CIT – much like the database of digital faces that are drawn on as foils in police line-ups. Clearly the adoption of a VR-CIT procedure would be a radical change. Thus, further systematic study of the

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<sup>2</sup> Indeed forensic crime scene documentation was carried out by the author for a homicide case on behalf of the West Midlands Police

VR-CIT as a memory detection test and the efficacy and reliability of a potential ‘VR superiority effect’ will be essential. Nonetheless these findings provide a promising start.

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## CHAPTER 6

**Fading memories:****Delayed testing and gradual onset stimuli reduce detection of concealed information****Abstract**

The Concealed Information Test (CIT) is a psychophysiological deception test used to detect whether a suspect recognises incriminating crime information they should otherwise not know. In contrast to lab-based studies, where a CIT is given soon after a mock crime, half of real forensic CITs are administered at least one month after the crime. Although crime information may still be explicitly remembered by suspects after longer periods, only a few studies have tested the impact a delay has on the magnitude of the CIT effect. In the current study participants carried out a mock crime, with half undergoing a CIT within a week and half over two months later. The CIT effect after two months was smaller than the one-week group, even after excluding forgotten trials. This indicated that the fading of memory over time decreases the CIT effect. A follow up experiment found similar results when stimuli in the CIT were faded gradually onto the screen to simulate weaker recognition. The findings indicate that memory strength is related to the CIT effect and therefore, where possible, suspects should be administered a CIT soon after a crime.

### Introduction

The fading of memories over time, or forgetting, is a well-studied topic in psychology. The prevailing explanation for how forgetting occurs is Interference Theory which proposes that memories interfere with one another over time (Underwood, 1957; Murayama, Miyatsu, Buchli & Storm, 2014). In a criminal context such as interviewing an eyewitness or a suspect, good memory is important. Weak memory is a particular problem therefore when testing perpetrators' concealed recognition for the crime. The Concealed Information Test (CIT) is a psychophysiological memory test used to detect a suspect's recognition of details about a crime that an innocent suspect should not know. Although the CIT is effective at detecting concealed recognition when details about the crime are adequately encoded (Verschuere, Ben-Shakhar & Meijer, 2011), it is much less efficient at detecting poorly encoded memories (Carmel, Dayan, Raveh, Naveh, & Ben-Shakhar, 2003). Typically, in CIT lab experiments participants learn details about a mock crime through either carrying out a task or watching a video, and then immediately take the CIT meaning that the crime details are rarely forgotten, and the memory is strong (Ben-Shakhar & Nahari, 2018). However, in the real-world, over 50% of forensic CITs are conducted at least one month after the crime (Hira, Sasaki, Matsuda, Furumitsu, & Furedy, 2002). Consider a crime where a suspect break into house, walks through the hallway to enter the living room before stealing some valuable items. If the suspect is caught and a CIT is administered shortly after the crime, they would likely recognize specific details about the appearance of the hallway and living room (e.g. the colour of the floor). However, if they are tested sometime after, it's likely that they would have forgotten individual features of the hallway (e.g. a coat stand, colour of the floor), or even completely forgotten the



hallway altogether. If such details are completely forgotten, the CIT cannot detect any recognition and therefore it's been recommended to administer CITs shortly after a crime while using salient, or central details that the suspect is unlikely to forget, e.g. the stolen item (Ben-Shakhar & Nahari, 2018). But what happens in the CIT when crime memory of the crime details reaches the threshold for recognition but has faded over time? Feature Matching Theory (Ben-Shakhar & Gati, 1987), an extension to orienting theory (Sokolov, 1963), might predict that the CIT recognition response, measured by skin conductance responses (SCR) would decrease as the number of features recognized in the CIT stimuli decreases (Ben-Shakhar & Gati, 1987).

A handful of CIT studies have tested the impact of delay CIT testing (for review see Ben-Shakhar & Nahari, 2018). In one study, participants tested one week after the mock crime showed smaller SCR CIT effects (the difference between responses to the crime and control items) compared to those tested immediately after – it was proposed to have occurred solely by participants forgetting crime details in the delay condition (Carmel et al., 2003). Similar results were found by Nahari and Ben-Shakhar (2011) who also tested participants one week after a mock crime. A reaction time-based CIT (RT-CIT) study found an effect of delaying testing (10 minutes, 24 hours or 1 week) only for crime details that were poorly encoded (Seymour & Fraynt, 2009). However, in another study by Gamer and colleagues (2010) the CIT effect was not affected by a 2-week time delay despite participants forgetting peripheral crime items. A suggestion for this finding may be because the CIT effect was a combination of skin conductance (SCR), respiration (RLL) and heart rate ( $\Delta$ HR) with the latter two not considered a measure of recognition (Verschuere, Meijer, & De Clercq, 2011; Klein Selle et al., 2016; Klein Selle,

Verschuere, Kindt, Meijer, & Ben-Shakhar, 2017). Finally, using a small number of salient crime details, Hira and colleagues (2002) found that P300 CIT detection was still possible up to a month and a year after the mock crime; note however that only nine participants were tested after a delay of one month and only five participants following a one year delay. Overall, the findings suggest that when suspects completely forget crime details (usually peripheral items) over a one to two-week period, detection of concealed information can decrease. The picture however is less clear for extended periods which correspond more to real-world CIT testing contexts. Furthermore, unlike participants in the lab, perpetrators are not instructed to remember the details about their crime and so will likely encode such details incidentally. Only the study by Carmel and colleagues (2003) tested the impact of not instructing participants to remember the crime before giving them a CIT; it was found that the CIT effect reduced - accounted for by crime details being forgotten.

In the current study, the effects of a long, realistic, time delay on the CIT was investigated. Participants were given a CIT either within a week or approximately two months following a mock crime task in which they were not explicitly instructed to remember any details. Following this experiment, a post-hoc follow up experiment was conducted to explore the effects of gradually fading CIT image stimuli onto the screen in an attempt to simulate reduced recognition due to forgetting. All studies were approved by the departmental ethics committee at the authors' institution.

## Experiment 1: Delayed Testing

### Method

#### Phase 1a – Mock Crime

Phase one of this experiment was conducted by a different researcher investigating the effect of time on participants' memory for their crimes (for details see [Sukumar, Wade & Hodgson, 2018](#)). In that experiment: participants met with an experimenter near the University of Warwick bookshop; were provided with an overview of the study including their right to withdraw; given the opportunity to ask any questions and; invited to provide consent and demographic information. In the mock crime participants were instructed to enter the *bookshop*, find a black *waist bag* placed on top of a yellow and white *box*, and steal a *wallet* inside this bag ([Figure 6.1](#)). Participants then returned this wallet to the experimenter outside the University *cinema* (crime details used in phase 2 in italics). A research assistant was covertly positioned in the bookshop to check that the participant followed the instructions and to intervene should any issues arise such as a member of the general public noticing the 'theft' and subsequently confronting the participant – note that this did not happen.

After the mock crime, participants were told they would receive an email with a questionnaire either one day or two months after committing the mock crime <sup>1</sup> - they did not receive feedback on their questionnaire responses. Following the questionnaire, participants were asked if they wished to take part in an additional

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<sup>1</sup> The questions were: 1. Where did you go on campus?; 2. Did you pass by the two pot plants?; 3. What did you do there?; 4. Which parts did you visit?; 5. Did you see a computer and telephone?; 6. Did you visit the Law section?; 7. Did you see a black bag?; 8. If yes, where was the black bag?; 9. Did you do anything with the black bag?; 10. Did you handle the black bag?; 11. Did you see anything in the black bag?; 12. If yes, what did you see in the black bag?; and 13. Did you take anything from the black bag?

phase of the experiment. If participants responded yes, they were invited to take part in the CIT experiment described in this chapter. Note that participants were not provided with a debrief until all data had been collected for both studies.

### **Participants**

Out of a potential fifty-nine participants who took part in the mock crime in phase 1, forty-four (27 women), aged between 18 - 44 years (*Mean* = 20.7, *SD* = 4.2), from the University of Warwick, asked to take part in phase 2 (i.e. the CIT experiment of the current study). Participants received an additional £4 for taking part in this twenty-minute experiment as well as the incentive of a £10 Amazon voucher prize for the person with the lowest 'lie detection score' in each delay group. Participants were randomly assigned to the delay condition. The study had two independent conditions (Delay: Short vs. Long) and normalized crime item SCR as the dependent variable. Finally, there were twenty-two participants in each delay condition. The sample size of this study was dependent on that of the Phase 1 study which was examining a different effect. Consequently, a power analysis was not appropriate in this experiment.

### **Phase 2 – The CIT**

On arrival, participants were provided with an overview of this phase of the study including their right to withdraw, given the opportunity to ask any questions and invited to provide consent and demographic information. Participants were not reminded of any details from the mock crime. Participants were then asked to imagine that they had been contacted by the authorities informing them that they were suspects in a crime that occurred either within the last week or over 2 months ago, and that they would therefore undertake a lie detection test. The experimenter explained what had happened in the crime (i.e. an item had been stolen from

somewhere on campus) without disclosing any of the crime details, before asking the participants if they knew anything else about the crime and whether they had committed it – all participants correctly lied by responding no. The experimenter then explained how the CIT would work and connected the physiological sensors (see Physiological Data section below). Participants were reminded to try to appear as innocent as possible by denying any knowledge of the crime.

The experimenter then gave the suspect a sheet containing all the CIT questions and stimuli including all control items and crime items (stimuli were unlabeled). Participants were not reminded of, or informed of, which items related to the crime. Previewing all items in the CIT prior to testing is permissible in the CIT (Verschuere & Crombez, 2008), as it reduces stimulus novelty (therefore removing this potential orienting response noise) and assists the experimenter in visually explaining the CIT procedure. Participants were told that five CIT blocks (Figure 6.2) would be presented in a random order with each beginning with the question (presented for eight seconds followed by a one second blank). Then ten images, each CIT image twice within the block, were presented sequentially (for four seconds) followed by a (four second) blank where the image was removed. Note that the first image presented in each CIT question was a buffer; a control item used to absorb the initial orienting to that item group. Participants were instructed to verbally respond with ‘no’ in response to each item. They were shown an example before questions were invited; the CIT then started.



Figure 6.1. Key events in the mock crime task (crime items in *italics*).



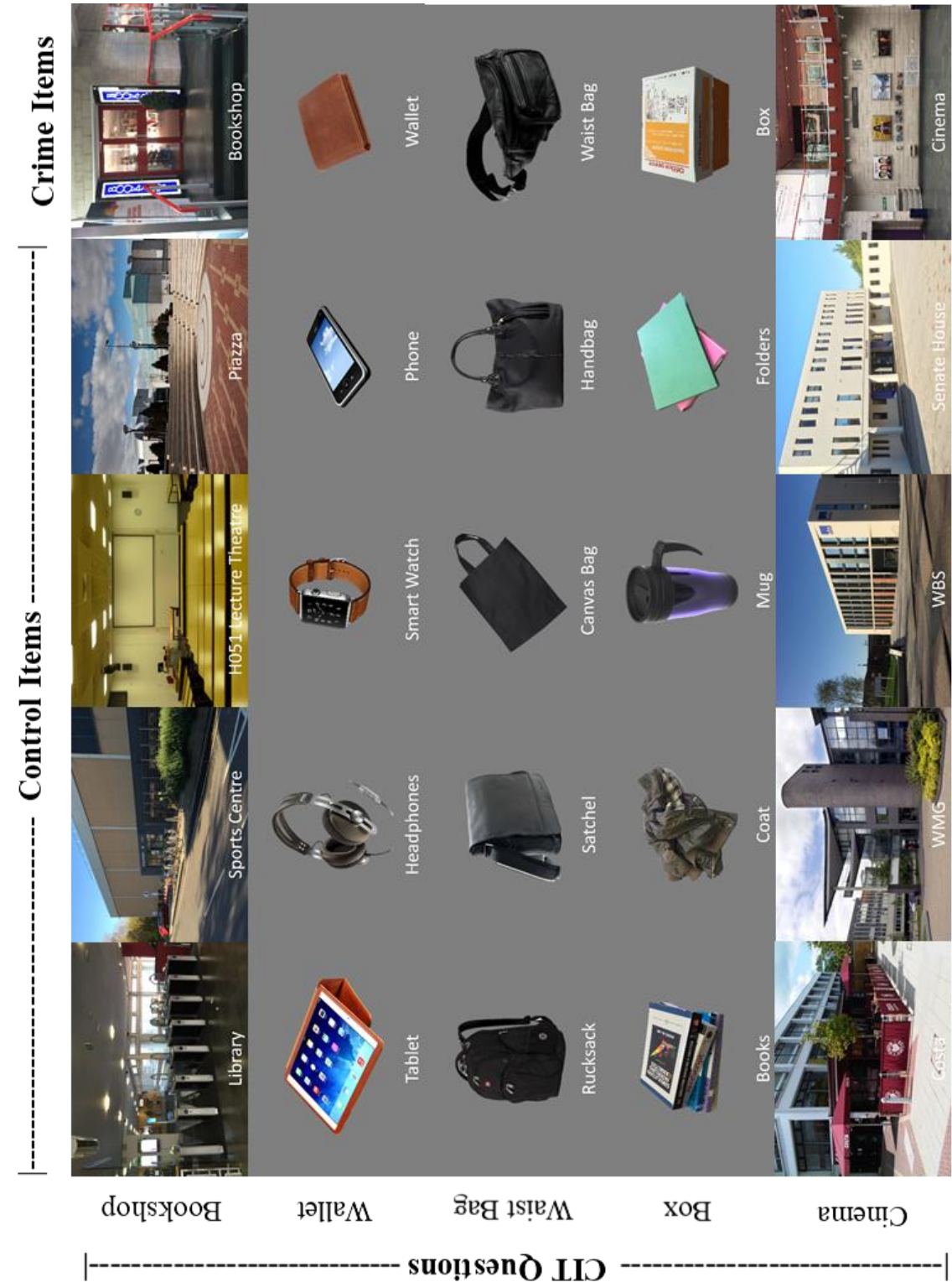


Figure 6.2. CIT stimuli used in this study.

### Physiological Data

Electrodermal activity (EDA) and heart rate were recorded using a MP36R data acquisition unit (*Biopac Systems Inc*) with pre-gelled disposable Ag/AgCL electrodes (EL507). EDA electrodes were attached to the distal phalanges of the first and middle fingers of the non-dominant hand with EDA signals sampled at 1000Hz at  $\times 2000$  gain and filtered using a 66.5Hz low pass filter. Skin conductance responses were defined as the difference in absolute magnitude of tonic skin conductance peaks and their respective peak onsets. Skin conductance peaks were identified using an *AcqKnowledge* v4.2 propriety algorithm (Kim, Bang & Kim, 2004) with parameters ensuring peak onsets were within a 0.5-5s window following stimulus presentation and maximum peaks within 10s (Gamer, 2011). Due to individual differences in physiological responsiveness, within-subjects standardised scores (z-scores) were calculated for each individual measure (Gamer, 2011). Signals were removed if the sensors became dislocated or dislodged during the experiment. Participants with a standard deviation of raw SCR responses below  $0.01\mu\text{S}$  were considered skin conductance non-responders and the EDA data were removed from analysis (Ben-Shakhar, 1985). Finally, the first trial in each CIT block, always a control item, was removed prior to analysis as its sole role is to absorb the initial orienting to that CIT item group.

**Post CIT Questionnaire.** After the CIT, participants were given a paper-based questionnaire consisting of multiple-choice questions to check that they had remembered the crime items. Participants were also asked to rate their motivation during the experiment on a scale of 1 (no motivation) to 6 (highly motivated) and their stress on a scale of 1 (no stress) to 6 (highly stressed). Participants were also asked to provide an open answer to the question: “*Did you do anything to try and*



*fool the polygraph test? If you did or didn't please bullet point below – either case is fine.*” Following this, participants were reminded that they would receive a debrief once all the data had been collected for the study.

## Results

### Manipulations

Participants in the short delay condition underwent the CIT between 1 – 8 days ( $M = 3.3$ ,  $SD = 1.9$ ), with no participants forgetting any crime details.

Participants in the long delay conditions underwent the CIT between 63 – 91 days ( $M = 72.6$ ,  $SD = 11.1$ ), with twelve (54%) participants forgetting at least one of the five crime details (six forgot one, five forgot two, and one forgot three). The forgotten items were either the box or the bag i.e. peripheral details with the cinema forgotten once. Five participants (three in the short delay group) were considered SCR non-responders and their data were excluded from the SCR analysis.

### Skin Conductance Responses

The main finding was that the CIT effect (normalized mean crime item) was larger for participants tested shortly after the mock crime,  $t(37) = 2.19$ ,  $p = .035$ ,  $d = .690$  ( $MD = .197$ ) (Figure 6.3). Additionally the CIT effect was large in the short delay,  $t(18) = 5.19$ ,  $p < .001$ ,  $d = 1.19$  ( $MD = .367$ ), and medium in the long delay group,  $t(19) = 3.02$ ,  $p = .007$ ,  $d = .676$  ( $MD = .170$ ). A final analysis revealed that the mean normalized SCR CIT effect was negatively correlated with the number of days between the crime and the CIT,  $r(39) = -.336$ ,  $p = .037$ .

### Excluding Forgotten trials

To establish whether the findings were simply due to forgetting, the same analysis above was run after removing forgotten crime trials - note that no forgetting occurred in the short delay condition. The findings were the same. The CIT effect

was again larger for participants tested shortly after the mock crime,  $t(37) = 2.17$ ,  $p = .37$ ,  $d = .725$  ( $MD = .222$ ) with a marginal medium sized CIT effect for the delay condition  $t(19) = 1.95$ ,  $p = .066$ ,  $d = .436$  ( $MD = .145$ ).

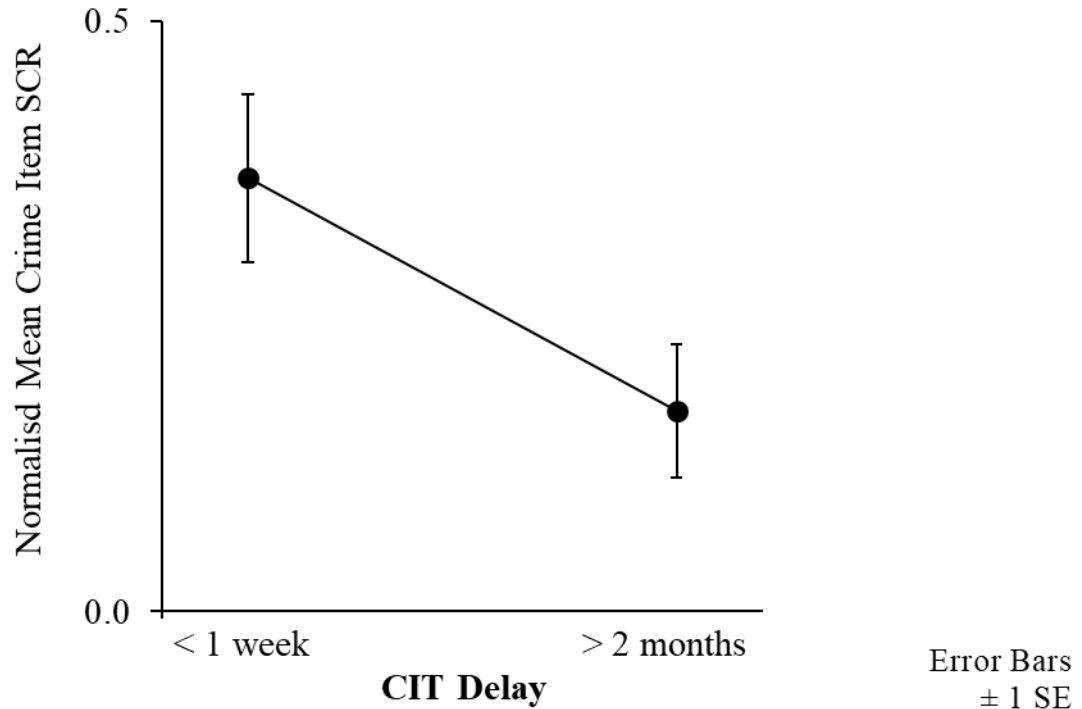


Figure 6.3. Experiment 1 - Mean normalized crime item SCR as a function CIT delay.

### Post CIT Questionnaire

Overall participants' self-reported motivation was high with Mean = 4.4,  $SD = 1.1$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>) with no difference between delay conditions  $t(42) = 1.32$ ,  $p = .192$ ,  $d = .537$  ( $MD = .45$ ). Overall, participants' self-reported stress during the CIT was low with Mean = 2.4,  $SD = 1.4$  (range = 1<sub>no stress</sub> to 6<sub>highly stressed</sub>), with no difference between delay conditions  $t(42) = .633$ ,  $p = .530$ ,  $d = .089$  ( $MD = .27$ ). Eight guilty participants (18%), five in each long delay condition, reported using some form of countermeasure to fool the test: four thought about something else; three tried to control their breathing; and one gave special attention to the control items. Countermeasure use did not differ between delay conditions,  $\chi^2(1, N = 44) = .424$ ,  $p = .515$ . Self-reported motivation to beat the CIT, stress during the CIT and

the use of countermeasures did not differ between delay groups, suggesting that these factors are unlikely to have significantly influenced the above findings.

## Discussion

The impact of a time delay between when a suspect commits a crime and when their memory for that crime is tested in the CIT, has only been investigated in a handful of previous studies (see review in [Ben-Shakhar & Nahari, 2018](#)). However, except for one study where the sample size was very small ( $n = 5$ ) and the P300 CIT was used ([Hira et al., 2002](#)), studies testing the impact of delayed CIT testing have only used delays of up to two weeks, whereas in the real-world, half of CITs are administered one or more months after the crime. In this experiment, participants carried out a mock crime, with half undergoing a CIT within a week and half over two months later. The results revealed that the CIT effect in the long delay group was smaller than the shorter delay group and that these findings stood even when trials forgotten by participants were excluded from the analysis. Nevertheless, in both delay conditions the CIT effect was significant with a medium to large effect size (short and long delay respectively).

In two studies where participants were tested one week after a mock crime, the CIT effect was reduced in the delayed condition due to participants forgetting ([Carmel et al., 2003](#); [Nahari & Ben-Shakhar, 2011](#)). These findings were similar to those found in the current study when participants were tested over two months after the crime. However, in the current work, further analysis suggested that these findings could not be accounted for simply by the presence of forgotten trials. This is interesting as it suggests that the CIT effect size relates to the strength of the memory. A simple explanation for this is that, although the crime memory reached the threshold for explicit recognition, memory for the crime items had faded over

time due to participants forgetting individual features of the object or scene memory e.g. the color of the crime scene floor. Feature Matching Theory proposes that SCR, related to orienting measured recognition, is monotonically related to the similarity between the encoded and test stimuli ([Ben-Shakhar & Gati, 1987](#)). Therefore, as the number of encoded features recognized at retrieval increases, so does the CIT effect increase. Accordingly, with good memory, SCRs are larger for crime items and smaller for control items, but this difference reduces as memory fades. A consequence of this is that over time, as individual features are forgotten, it becomes more difficult to distinguish which of the five CIT stimuli (four of which are controls) is the crime item. SCRs should therefore decrease to crime items and increase to control items thereby reducing the CIT effect ([Marchand, Inglis-Assaff, & Lefebvre, 2013](#)). This is indeed what was found here, which matches the predictions from Feature Matching Theory accounts. As others have suggested, practically the CIT should be administered as soon as possible after the crime to maximize detection of concealed information ([Ben-Shakhar & Nahari, 2018](#)). Nevertheless, the CIT effect size was still adequate even after two or more months later, suggesting it is relatively robust to the effects of time.

### **Experiment 2: Gradual onset of stimuli**

In the previous experiment, it was found that the CIT effect reduced when participants were tested after a two-month period, as presumably the mock crime memory had faded. It was suggested that this was compatible with Feature Matching Theory whereby physiological orienting is related to the similarity between the test stimuli and the associated memory representation ([Ben-Shakhar & Gati, 1987](#)). To further explore this effect, a follow up experiment was conducted.

In this experiment, the author proposes that recognizing an image after memory has faded over time is similar to trying to recognize an image that is blurred or faded like an old photograph. Previous research has found that it's more difficult and takes longer to recognise blurred and faded images, particularly faces, as the processing of individual features in the image suffers ([Costen et al, 1994](#); [Collishaw & Hole, 2000](#); [Lewis & Edmonds, 2003](#); [Hole, George, Eaves, & Rasek, 2002](#); [Brockdorff & Lamberts, 2000](#)). Experiment 1 demonstrated that the CIT effect reduces over time, even when stimuli are explicitly recognized with Feature Matching Theory, suggesting this is due to individual features of a memory being forgotten. Similarly, then, if CIT images are gradually faded onto the screen (rather than appearing with an abrupt onset), this would reduce the recognition of individual features, particularly at onset, and result in a reduced CIT effect. This was tested by gradually fading the stimuli onto the screen so that the features would not be immediately clear to simulate retrieval of faded memories i.e. it is more difficult and takes longer. In this situation, just like in Experiment 1, Feature Matching Theory predicts a decrease in SCR-orienting measured recognition, to gradually appearing crime items compared to those presented using a standard abrupt onset where individual features are immediately clear. Heart rate was also recorded as a measure

of arousal inhibition, which was unlikely to have been affected by the stimuli onset (Verschuere, Meijer, & De Clercq, 2011; klein Selle et al., 2016; klein Selle et al., 2017).

However, an alternative prediction is that the CIT effect could actually be larger with gradually-onsetting stimuli. This follows because the presentation of a CIT item causes an orienting response due to two components. One response is related to the crime/non-crime status of the stimulus, the other is related to the resulting rapid change in luminance (Turpin, Schaefer & Boucsein, 1999; Turpin & Siddle, 1979) which is unrelated to the crime/non-crime status of the item. By removing the luminance-based component we might also remove noise associated with that component leading to an improved signal-to-noise ratio for crime versus non-crime items. In addition, given that there is a limit to the size of an individual's SCR before saturation occurs (Boucsein, 2012), when image stimuli are presented abruptly, the orienting component caused by the luminance change would compress the available range for the SCR signal that relates to the significance of the crime image. This would in turn result in a smaller CIT effect overall when stimuli are presented with an abrupt luminance onset.

These alternative predictions are tested here. Participants watched a mock crime video before undergoing a CIT with both SCR and heart rate recorded. Half the CIT images were gradually presented whilst half had an abrupt immediate onset.

## Method<sup>2</sup>

### Participants

Forty self-selected participants (26 women), aged between 18 - 36 years ( $M = 20.8$ ,  $SD = 3.2$ ) were recruited through a convenience sample of staff and students at the University of Warwick. The sample size was chosen to be similar to the previous experiment for comparison and therefore no power analysis was conducted.

Participants received no payment for partaking in the 40-minute testing session but did have the opportunity to receive their 'lie detection score' and a chance to win a £25 Amazon voucher if they obtained the lowest 'lie detection score'. The study had a 2 (Onset: Gradual vs. Abrupt) x 2 (Order: Gradual 1<sup>st</sup> vs. Gradual 2<sup>nd</sup>) two-way mixed-design with Order as the between-subject factor and normalized crime item SCR and Heart Rate change ( $\Delta HR$ ) as dependent variables. Participants were equally split across the order conditions (whether they saw items gradually or immediately first) and assigned in an alternating fashion.

### Procedure

The procedure, instructions, mock crime video, CIT, post CIT questionnaire and physiological data processing method in this experiment was the same as that in the computer (control) condition in Experiment 2, Chapter 4. In brief, participants watched a mock crime video where they stole a laptop from a bag in a lecture theater. Eight crime details were used in the CIT. The key difference was that half of the CIT

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<sup>2</sup> A prior data collection round was carried out for this experiment. However, due to a programming error being present throughout this initial data collection run, the stimulus onset was not counterbalanced. Therefore, these data were discarded. For completeness, in this initial experiment, forty-three self-selected participants (26 women), aged between 18 - 36 years ( $M = 20.8$ ,  $SD = 3.2$ ) were recruited in the same way with the same incentives as the experiment described in this study. The methodology was also identical to that described in this study and eight participants were SCR non-responders and no trials required removal due to movement artefacts.

stimuli were presented instantly on the screen for five seconds i.e. with an abrupt onset, whilst half were gradually faded in a linear fashion onto the screen over the full five seconds. This order was counterbalanced, participants either saw four CIT questions gradually presented and then four questions immediately presented or vice versa.

**Exclusions.** Thirteen trials (0.81%) were removed from analysis due to large movement artifacts: seven posture shifts; three large head movements; one cough; one large hand movement; and one yawn. A technical error in the physiological data collection resulted in the removal of EDA and ECG data for one participant; and ECG data from two participants. Finally, in total, four participants were considered SCR non-responders and their data were excluded from the SCR analysis.

## Results

### Skin Conductance Responses

The main finding was that items presented gradually resulted in a smaller SCR CIT effect. Mean normalized crime item SCRs were analyzed using a 2 (Onset: Gradual vs. Abrupt) x 2 (Order: Gradual 1<sup>st</sup> vs. Gradual 2<sup>nd</sup>) two-way mixed measures ANOVA. This revealed a significant main effect of: Onset,  $F(1, 34) = 5.3, p = .028, MSE = 2.30, \eta_p^2 = .135$ , where abrupt-onset stimuli elicited larger SCRs overall (Figure 6.4) but no main effect of Order,  $F(1, 34) = .593, p = .447, MSE = .176, \eta_p^2 = .017$ . There was no significant Onset x Order interaction,  $F(1, 34) = .163, p = .689, MSE = .071, \eta_p^2 = .005$ . Note that for abrupt onsets, the SCR CIT effect was large,  $t(35) = 6.60, p < .001, d = 1.10 (MD = .683)$  whereas it was medium for gradual onsets,  $t(35) = 3.34, p = .002, d = .556 (MD = .321)$  and respectively.



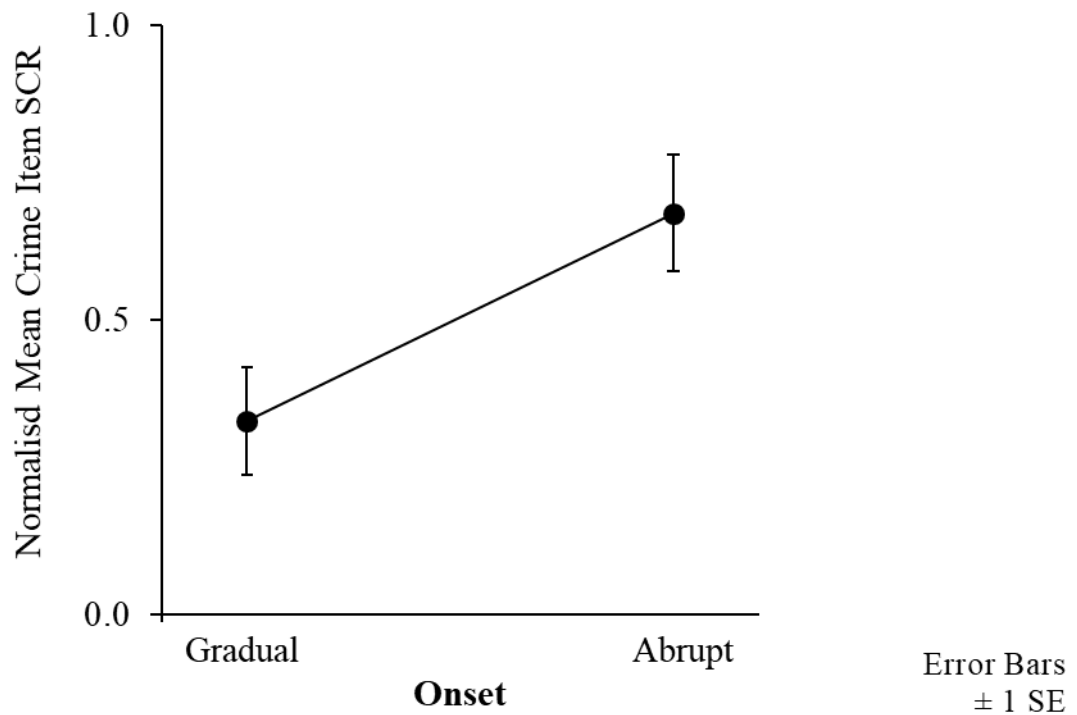


Figure 6.4. Experiment 2 - Mean normalized crime item SCR as a function of Onset.

### Heart Rate Change

The main finding was that heart rate deceleration was greater for crime items compared to controls with no effect of Onset. Mean normalized crime item  $\Delta$ HR were analyzed using a 2 (Onset: Gradual vs. Abrupt) x 2 (Order: Gradual 1<sup>st</sup> vs. Gradual 2<sup>nd</sup>) two-way mixed measures ANOVA. This revealed no significant main effect of Onset,  $F(1, 35) = .367, p = .548, MSE = .156, \eta_p^2 = .010$  or Order,  $F(1, 35) = 1.69, p = .202, MSE = .439, \eta_p^2 = .046$  (Figure 6.5). There was also no significant Onset x Order interaction,  $F(1, 35) = .481, p = .493, MSE = .204, \eta_p^2 = .014$ .

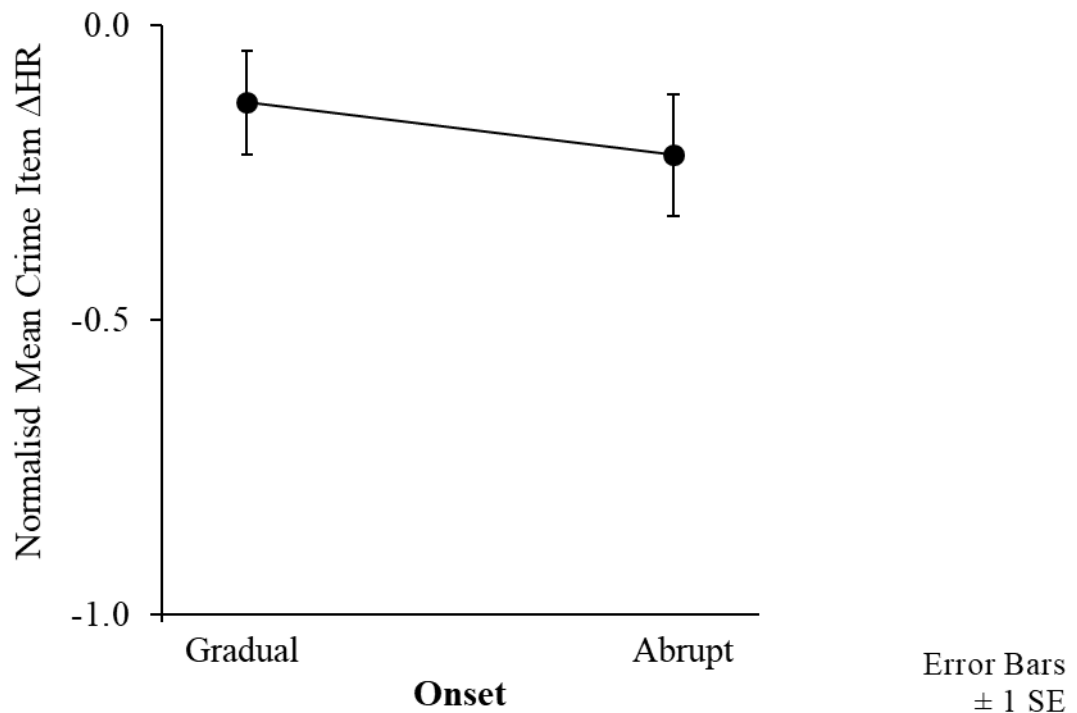


Figure 6.5. Experiment 2 - Mean normalized  $\Delta HR$  as a function of Onset.

### Post CIT Questionnaire

Participants correctly recalled 99% of crime items, with fifteen participants forgetting one of the eight crime items and one participant forgetting two. Overall participants' self-reported motivation was high with Mean = 5.25,  $SD = 0.74$  (Scale = 1<sub>low</sub> to 6<sub>high</sub>) and self-reported stress during the CIT was low with Mean = 3.15,  $SD = 1.23$  (range = 1<sub>no stress</sub> to 6<sub>highly stressed</sub>). Fourteen participants (35%), reported using some form of countermeasure to fool the test: five tried to control their breathing; three tried to remain calm; two thought about something else; two gave special attention to the control items; and one pushed their tongue to the roof of their mouth.

**Discussion**

This experiment was conducted as a follow up to Experiment 1, where the CIT effect was found to decrease for crime information explicitly remembered but weakened over time. Participants saw both images that had either a gradual/faded or immediate/abrupt onset. There were two opposing predictions: First, recognizing gradually-onsetting images would be similar to recognizing images after memory had faded over time, resulting in a reduced CIT effect. Second, using gradual onset stimuli might result in an increased CIT effect by removing the (potentially noisy and response saturating) non-crime related response caused by the luminance signal itself. If the latter prediction was verified then this would have immediate and obvious implications for improving the CIT via a very easy to implement change. The results supported the first prediction with gradually onsetting stimuli producing a reduced SCR CIT effect. The initial hypothesis then, although speculative, appears to be supported. The results for the heart rate measure were not affected by the image onset type, however, this isn't surprising as heart rate has been shown to be a measure of deception based arousal inhibition rather than recognition ([Verschuere, Meijer, & De Clercq, 2011](#); [Klein Selle et al., 2016](#); [Klein Selle et al., 2017](#)).

### General Discussion

The main aim of this study was to assess the impact of taking a CIT two months after a crime was carried out. Despite over half of real-world CITs being administered over a month after the crime (Hira et al., 2002) only a few studies have tested the effect of delayed CIT testing (see review in Ben-Shakhar & Nahari, 2018). Amongst those studies (Carmel et al., 2003; Nahari & Ben-Shakhar, 2011), only one has administered a CIT after a two week delay, however that P300 CIT experiment did not report an effect of delayed testing, possibly due to the small sample size ( $n = 9$ ) (Hira et al., 2002). In the current study, participants underwent a CIT either within a week of the mock crime or over two months later. The results revealed that the CIT effect reduced when participants were tested more than two months after and this result remained even after excluding forgotten trials. In line with the Feature Matching Theory for physiological orienting (Ben-Shakhar & Gati, 1987), a faded memory for crime items resulted in a reduced SCR CIT effect, as presumably participants' memory for individual features decreased (Marchand, Inglis-Assaff, & Lefebvre, 2013). This negative impact on delayed CIT testing was similar to that found in previous work (Carmel et al., 2003; Nahari & Ben-Shakhar, 2011).

Experiment 2 was a post-hoc follow up to Experiment 1. Participants saw CIT images presented either gradually or abruptly on the screen. The idea was that recognizing images that were gradually faded onto the screen (over five seconds) would be similar to trying to recognize an image from memory faded over time. Alternatively, gradually fading images may have resulted in the reduction of SCR noise and signal compression, caused by a luminance change, thereby resulting in an increased CIT effect. The results were similar to those in Experiment 1 with a reduced CIT effect for faded stimuli. Previous research has found that it's more

difficult and takes longer to recognise blurred and faded images, as the processing of individual features in the retrieval cue suffers much like that for memory faded over time (Costen et al, 1994; Collishaw & Hole, 2000; Lewis & Edmonds, 2003; Hole et al., 2002; Brockdorff & Lamberts, 2000). Finally, as predicted the heart rate measured arousal inhibition was not affected by onset type as it is not considered a measure of recognition (Verschuere, Meijer, & De Clercq, 2011; klein Selle et al., 2016; klein Selle et al., 2017).

Seemingly then, both SCR findings in these experiments can be explained by Feature Matching Theory. When the memory is weaker, due to a longer delay between encoding and retrieval, the individual features of the test stimulus become less clear, thereby reducing the feature match which monotonically reduces the SCR measured orienting. The same effect should happen when the individual features in the test stimuli are less clear due to the stimuli having a gradually faded onset. This is what was found in this study.

To the author's knowledge this is the first study to test the effects of: i) an extended delay i.e. over two months, between crime and CIT; and ii) gradually presented image stimuli in the CIT. In conclusion, the CIT should be administered as soon as possible after the crime and abrupt onsets should be used.

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## CHAPTER 7

**Upstanding or underhand?****Verticality and deception in the reaction-time  
concealed information test****Abstract**

The reaction-time Concealed Information Test (RT-CIT) is a cognitive deception detection task used to determine whether a suspect recognizes crime information they shouldn't know. Verticality (relative positioning of stimuli in the vertical dimension) has been linked to various metaphoric associations such high/up equating to positive/moral whereas low/down equals negative/immoral. In the RT-CIT, guilty participants deceptively deny recognition of crime items whilst truthfully responding to controls. For guilty participants, RTs are typically slower for crime items compared to controls, which is attributed primarily to response inhibition – this is the RT-CIT effect and can be used to detect deception. Over three experiments in this study, verticality was found to interact with the RT-CIT effect. This was mainly caused by slower RTs to crime items when they were presented on top of the screen compared to the bottom. The findings suggest that metaphorical associations of verticality in deception, i.e. up, is congruent with truth but incongruent with lies, can be used to increase RT-based deception detection.

### Introduction

The reaction time Concealed Information Test (RT-CIT) is a cognitive deception detection test used to detect participants' concealed recognition of crime related information that an 'innocent' person would not know ([Verschuere, Suchotzki, & Debey, 2014](#)). Compared to the well-established physiological-based CIT which has been researched and applied in the field for decades ([Osugi, 2011](#)), the RT-CIT is a relatively new paradigm only investigated in a few dozen studies. In RT-CIT experiments, participants assigned 'guilty' typically encode crime details through watching or carrying out a mock crime. In the RT-CIT, crime details (aka probes) are randomly placed amongst control items (aka irrelevants) at a ratio of approximately 1:4 (crime to control items). All CIT stimuli are then presented on a computer, sequentially, rapidly (< a second) and with multiple repetitions with each stimulus requiring a response. In the test, participants respond to indicate whether they know the stimulus relates to the crime or not. Responses are either truthful i.e. "no" to the control items or deceptive i.e. "no" to the crime items they are concealing recognition of. To ensure all stimuli are adequately processed, additional control items are designated as target items, which the participant memorizes prior to the test and must respond ("yes") to.

The result is that guilty participants take longer to respond to crime items compared to control items - the RT-CIT effect; no difference is expected for the innocent participants. Studies reveal that the RT-CIT effect is large  $d = 1.30$  ( $1.06 - 1.54$  CI<sup>95%</sup>) ([Suchotzki, Verschuere, Van Bockstaele, Ben-Shakhar, & Crombez, 2017](#)) and results high detection rates with low false positive ( $AUC = .82$   $n = 981$ , [Meijer et al., 2016; Granhag, Vrij & Verschuere, 2015](#)).

The RT-CIT effect, i.e. a slowing of responses to crime items, is largely believed to be due to response inhibition experienced by guilty participants as a result of having to resolve the internal conflict between knowing that they do recognize the stimulus (truthfully), but having to suppress this and respond (deceptively) claiming that they do not (Debey, Ridderinkhof, De Houwer, De Schryver, & Verschuere, 2015). Naturally, this conflict can also result in an increased number of errors for crime items, e.g. pressing ‘Yes’ to the crime items or ‘No’ to the target items (Suchotzki et al., 2017). Other executive functions have also been suggested as mechanisms relating to the cognitive cost to deception such as working memory and task switching (Suchotzki et al., 2017; Ambach, Stark & Vaitl, 2011). Accordingly, studies have investigated the effects of activating other executive functions in order to interfere with response inhibition and potentially increase the RT-CIT effect (Ambach, Stark & Vaitl, 2011; Hu, Evans, Wu, Lee & Fu, 2013; Debey, Verschuere & Crombez, 2012). In one study, a dot-probe based secondary task was incorporated alongside an RT-CIT which resulted in increased detection rates explained as due to an overloading of cognitive resources (Hu et al., 2013). Similarly, in another experiment using the Sheffield Lie Test, lying was found to require more executive control than truthful responses (Debey, Verschuere & Crombez, 2012). The effects of working memory and shifting have also been manipulated in the RT-CIT revealing that in dual-task conditions, the CIT effect increased (Visu-Petra, Varga, Miclea & Visu-Petra, 2013). As opposed to manipulating cognitive effort, one study explored the impact of valence on the RT-CIT by presenting a ‘virtual investigator’ (a face with either a neutral, happy or angry expression) on screen alongside each RT-CIT trial (Varga, Visu-Petra, Miclea, & Visu-Petra, 2015). The results indicated that the RT-CIT effect increased when

participants saw a positive expression, compared to a neutral expression, and decreased for negative expressions (Varga et al., 2015). This finding suggests that emotional valence can interact with deceptive responses in the RT-CIT when the valence is incongruent with the (negative) crime item. Evidently, RT-based deception tests can be influenced by activation of additional cognitive operations, which is line with the theories of “independent and interdependence” of executive functioning (Miyake & Friedman, 2012; Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000). It is important to pursue studies like the ones described above, as it can provide important theoretical insights into the cognitive processes involved in deception, as well as reveal techniques for increasing detection rates in the RT-CIT.

An alternative potential approach to exploring the effects of valence in cognitive RT paradigms might be based on the *verticality-manipulation taxonomy* proposed by Cian (2017). Verticality is the relative positioning of a stimulus along the vertical dimension (e.g. high/top, low/bottom) which has been shown to relate to various metaphorical associations. Cian (2017) provides an excellent introduction to this concept as well as a systematic review of the verticality and conceptual metaphor literature which explores the relationship between vertical-spatial positioning and metaphorical associations. There are four main approaches for exploring the effects of verticality, which include manipulating: an object's placement; observers' vertical position; participants' imagined height; and abstract concepts e.g. dominance (Cian, 2017). The metaphorical associations typically studied are: power (e.g. less powerful groups identified faster when presented in a low vertical position and vice versa, Schubert, 2005; Robinson, Zabelina, Ode & Moeller, 2008; Lamer & Weisbuch, 2019); concreteness (e.g. objects placed low are perceived as heavier, Deng & Kahn, 2009); direction (e.g. preference for living in northern locations, Meier et al., 2011);

rationality/emotions (e.g. preferring emotional elements as lower than rational, [Cian et al., 2015](#)); and valence (e.g. recognizing positive words faster when they are presented on the top screen verses the bottom and vice versa, [Meier & Robinson, 2004](#); [Freddi, Cretenet & Dru, 2014](#)). Studies investigating valence-based associations have found that people also later recall the placement of positive stimuli (e.g. God, [Meier et al., 2007](#)), as higher on the screen than negative stimuli ([Crawford et al., 2006](#)). Similarly, people recognize moral words (e.g. truth), faster on the top of the screen than immoral (e.g. deceit) ([Meier, Sellbom & Wygant, 2007](#)).

So how might verticality and metaphorical associations relate to RT-based deception detection? In the RT-CIT, guilty participants who recognize the crime item must respond deceptively. For guilty participants only, crime items are negative, relative to control items, and require a deceptive (immoral) response. Based on previous verticality findings, placing crime items lower e.g. at the bottom of the screen, could facilitate faster responding. Conversely, when crime items (presumed to be negative/immoral) are presented on top of the screen, the incongruence between the vertical associations of top (i.e. positive, moral) should result in slower responses. As this slowing of reaction times is in the same direction as response inhibition in the RT-CIT, then presenting crime items on top could increase the RT-CIT effect.

The current study explores the effects of verticality in the RT-CIT by presenting image stimuli, some of which require deceptive responses, either at the top or bottom of the screen. In Experiment 1, three different configurations of stimulus verticality were tested in order to establish which one elicited the largest RT-CIT effect and whether there was any interaction with verticality. In Experiment 2, the optimal vertical configuration established in Experiment 1 was implemented as

a replication. In both Experiments 1 and 2, autobiographic scene stimuli were used as the crime items, meaning no innocent group was tested. Therefore, in Experiment 3, a mock crime video was used so that both guilty and innocent participants were tested to ascertain whether the verticality effect was unique to guilty participants. All studies were approved by the departmental ethics committee at the author's institution.



### **Experiment 1: Vertical RT-CIT Pilot**

Verticality has not been manipulated in the RT-CIT before and it was uncertain whether it would reduce or indeed negate the RT-CIT effect, due to participants now having to, in effect, search for the stimulus (top or bottom). Therefore, in this experiment three display configurations (labeled A, B and C) were tested to determine the optimal configuration in terms of producing the largest RT-CIT effect size. Photographs of University campus scenes were used as crime images with matched scenes acting as controls. Participants concealed recognition of the crime items in an RT-CIT that had a vertical dimension with images presented at the top or bottom of the screen. Therefore, the experiment had a three-way (Configuration: A, B and C) x 2 (Location: Bottom vs. Top) x 2 (Item: Crime vs. Control) mixed design with configuration as the between subject factor and RTs and error rates as dependent variables. Following analysis of location and configuration on the RT-CIT effect (crime minus control), the RT-CIT effect was computed for each configuration, collapsed over location, to determine which vertical configuration elicited the largest CIT effect – this configuration was then replicated in Experiment 2. Note that the stimuli, procedure and CIT structure were the same as that used in Experiment 3, Chapter 2 with the main difference being the addition of vertical configuration.

### **Method**

#### **Participants**

The closest study identified by the author that used a reaction time deception test (an Implicit Association Test), to investigate a verticality effect was conducted by Meier et al., (2007). They found that participants were faster to categorize God-related words when they appeared on the top versus the bottom of the computer

screen,  $p < .001$ ,  $\eta_p^2 = .42$ . A power analysis using G\*Power (Faul, Erdfelder, Lang, & Buchner, 2007), assuming a medium effect size of  $\eta_p^2 = 0.4$ , and  $\alpha = 0.05$  for a single group, suggested a minimum sample size of 23 participants would be sufficient for a power of 0.95. Therefore, a sample size of twenty-six per display configuration was chosen. Seventy-eight participants (54 women), aged between 18-27 years ( $Mean = 19.6$ ,  $SD = 1.6$ ), were recruited through a University online participant panel at the author's institution. Participants received £3 payment for taking part in the 30-minute testing session. Participants were split equally across the three display configurations and assigned based on the session they chose to sign up to.

### Materials

The stimuli were photographs of scenes that typically contained landscapes, buildings, and other structures - the same stimuli as in Experiment 3, Chapter 2. The autobiographic probe images (i.e. 'crime' items), were five images of various scenes of the participants' University campus (examples in Figure 7.1). For each probe item, four matched irrelevant scene stimuli were sourced using Google's Reverse Image Search function, with the probe items as reference images. In addition to the probe and irrelevant stimuli were five images of another University that served as target items. All images were open source, cropped to remove potential noise (e.g. people), were resampled to 1366 x 768 pixels and presented on a 21" LCD monitor, 16:9 aspect ratio at a resolution of 1920 x 1080 pixels. Participants sat approximately 40cm from the screen with the center of the screen at approximately eye level. Examples of stimuli used in Experiment 1 are shown in Figure 7.1.



Figure 7.1. Examples of control, crime and target scene images used in Experiments 1 and 2.

### Vertical Configurations

Three different presentation configurations were used in Experiment 1. In configuration A, the image filled the whole top or bottom half of a landscape-oriented computer screen with no cropping. In configuration B, the image filled the whole top or bottom half of a portrait-oriented computer screen with equal cropping to allow the image to fill the height of half the screen without changing the aspect ratio. In configuration C the image center filled 80% of the top or bottom half of a landscape computer screen with no cropping (Figure 7.2).

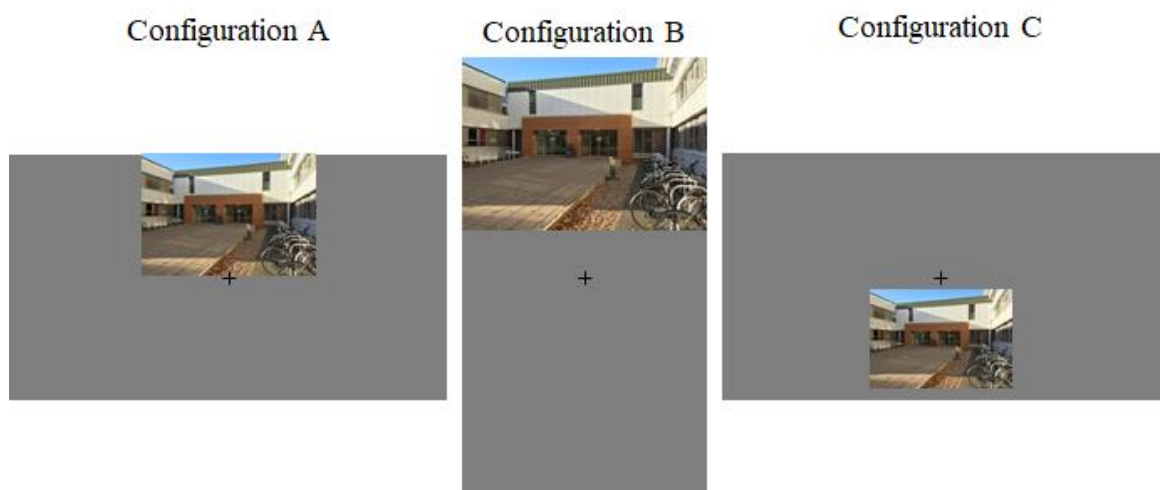


Figure 7.2. The three different display configurations used in Experiment 1.

### The CIT

The RT-CIT was made up of 450 images consisting of 15 blocks of 30 images. Each block of 30 images contained five CITs and each CIT consisted of six

images: a probe, a target, and four irrelevant images. There was a short break of 3000ms after each block and a longer break of 30s after every three blocks. The image duration was 800ms with a randomly selected inter-stimulus interval of either 500, 750 or 1500ms. Items within each block were presented sequentially in a random order with the constraint that two probes (crime items) could not occur consecutively. The targets were randomly presented within each block and were the same for all participants. Target items were not analysed as they were only used to ensure participant engagement with the stimuli. The data from participants with error rates (i.e. pressing “Yes” to a probe item or “No” to a target) above 50% were removed from further analysis as it is unlikely that they were following the task instructions. Responses faster than 200ms or slower than 800ms were removed, as recommended by Verschuere and colleagues (2015). Incorrect responses were also removed from the RT analysis. Due to potential individual differences in overall speed across the conditions, within-subjects standardised scores (z-scores) were calculated for each RT response (Ben-Shakhar, 1985).

### **Procedure**

Participants completed the experiment in a computer lab in groups of 10-18 people. They were provided with an overview of the study procedure, given the opportunity to ask questions and then provided consent and demographic information. Participants were informed of their right to withdraw at any point without penalty or reason. Participants were then asked to imagine that they “*are an undercover spy from Warwick University and have infiltrated New York University to steal their latest research. New York University Security suspects a mole and are therefore requiring all staff to sit a ‘lie detection test.’ Their ‘lie detection test’ assumes that spies will be slower to recognise and make more mistakes when they*

*respond to images of New York University. They are also hoping to catch spies that accidentally respond “Yes” to images of Warwick University who they believe are the prime suspects.”* The participants were then given five images of ‘New York University’ and told to memorise these to help them beat the lie detection test.

Participants were then told that *“during the ‘Lie Detection Test’ you will be shown a series of items of scenes. Many of these items will be unfamiliar to you except the ones relating to Warwick University (which you must keep secret) and the scenes of New York University which you have just memorised. Each image will appear for around 1 second with less than a second gap between them. Using the keyboard, please respond to these images as fast as you can making as few errors as possible! The question to consider for each image is ‘Do you recognise this scene?’”*

Participants were instructed to press the LEFT KEY for “Yes” responses, i.e. New York University Images (Targets), and the RIGHT KEY for “No” i.e. University of Warwick (Probes) and any other random images (Irrelevant). Participants were given the opportunity to ask any questions before completing a practice test consisting of two blocks of trials (60 images). During the practice stage only, if the response was incorrect e.g., “Yes” response to a probe, the words “Wrong” were displayed until the start of the next trial. If a response time exceeded the deadline of 800ms the words “Too Slow” were displayed until the start of the next trial. Participants were aware that this information would not be provided following the practice stage. Finally, participants were instructed that they did not need to consider or respond differently to items placed on either the top or bottom of the monitor. Following the practice, test participants completed the main test followed by debriefing.

## Results

### Reaction Times

The data from one participant from configuration C was removed from all further analysis due to error rates above 50% (52%) and another due to a technical error in the stimuli program. Including target items, trials that exceeded the response deadline (6.9%), were faster than 200ms (0.3%) and incorrect trials (8.4%) were removed from the analysis – note, incorrect responses were used for the error analysis.

Mean RTs were analyzed using a 3 (Configuration: A vs. B vs. C) x 2 (Location: Top vs. Bottom) x 2 (Item: Control vs. Crime) three-way ANOVA with Configuration as the between-subject factor. This revealed a significant main effect of Item,  $F(1, 73) = 32.0, p < .001, MSE = 15667, \eta_p^2 = .305$ , overall RTs were slower to crime items compared to control items (Figure 7.3) and Configuration,  $F(2, 73) = 3.34, p = .041, MSE = 29896, \eta_p^2 = .084$ . There was no significant main effect of Location,  $F(1, 73) = 1.02, p = .316, MSE = 467, \eta_p^2 = .014$ . There was no significant two-way interaction between: Location and Configuration,  $F(2, 73) = .037, p = .964, MSE = 16.8, \eta_p^2 = .001$  or; Item and Configuration,  $F(2, 73) = .823, p = .443, MSE = 430, \eta_p^2 = .022$ . There was, however, a significant two-way interaction between: Location and Item,  $F(1, 73) = 6.52, p = .013, MSE = 1732, \eta_p^2 = .082$  which appears to be driven by slower reaction times to crime items when presented on the top of the monitor,  $t(75) = 2.2, p = .031, d = .253, (MD = 7.29)$ . Finally, the three-way interaction was non-significant,  $F(2, 73) = 1.79, p = .174, MSE = 476, \eta_p^2 = .047$ .

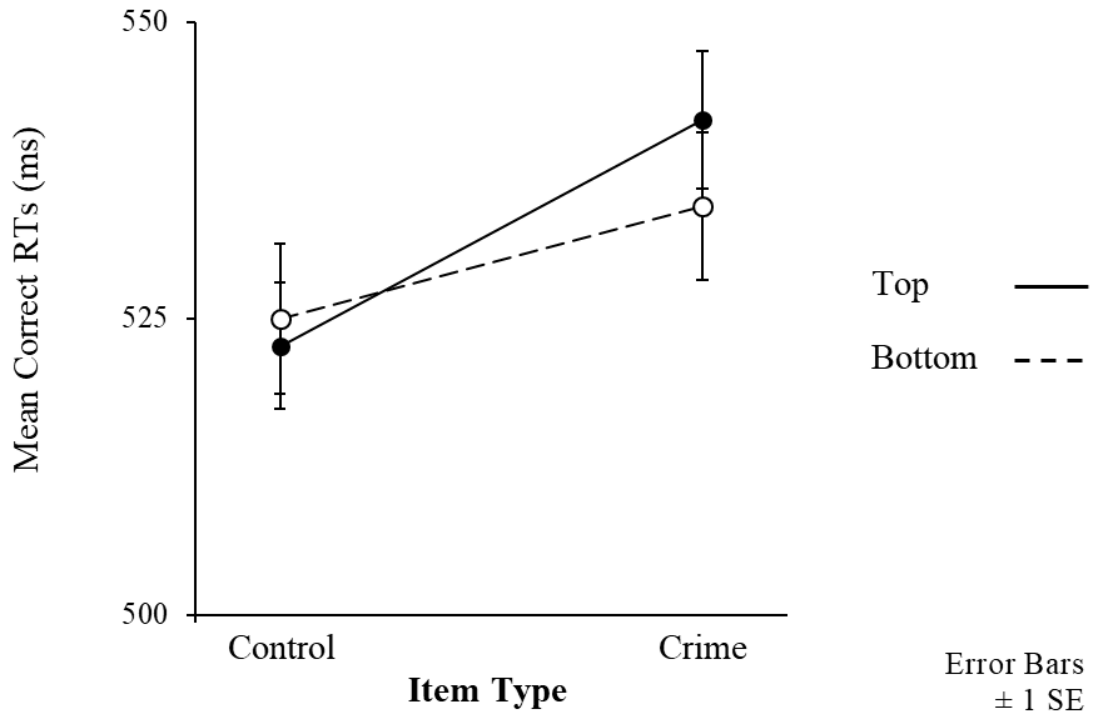


Figure 7.3. Experiment 1 - Mean correct RTs as a function of Item Type and Vertical position.

### Error Rates

Overall error rates were low ( $M = 4.0\%$ ,  $SD = 9.7$ ) and error rates were analyzed in the same way as the RTs. This revealed a significant main effect of Configuration,  $F(2, 73) = 3.21$ ,  $p = .046$ ,  $MSE = 718$ ,  $\eta_p^2 = .081$ , where Bonferroni corrected t-tests revealed marginally higher error rates for Configuration B compared to A and C ( $p = .084$ ,  $MD = 4.65$  and  $p = .110$ ,  $MD = 4.51$  respectively). No significant main effect was revealed for Item,  $F(1, 73) = 1.10$ ,  $p = .297$ ,  $MSE = 129$ ,  $\eta_p^2 = .015$  or Location,  $F(1, 73) = 2.72$ ,  $p = .104$ ,  $MSE = 23.9$ ,  $\eta_p^2 = .036$ . There was no significant two-way interactions: Location x Configuration,  $F(2, 73) = .097$ ,  $p = .908$ ,  $MSE = .851$ ,  $\eta_p^2 = .003$  or; Item x Configuration,  $F(2, 73) = 2.88$ ,  $p = .062$ ,  $MSE = 356$ ,  $\eta_p^2 = .073$ ; or Location x Item,  $F(1, 73) = 2.27$ ,  $p = .136$ ,  $MSE = 16.1$ ,  $\eta_p^2 = .030$ . The three-way interaction was also non-significant,  $F(2, 73) = .480$ ,  $p = .621$ ,  $MSE = 3.41$ ,  $\eta_p^2 = .013$ .

### Discussion

Given that positional manipulations in the RT-CIT had not been previously reported, it was unclear as to the optimal way to display the image stimuli. Therefore, three groups of participants took part in an RT-CIT with three different display configurations. Although there was no main effect of configuration or interaction with the other factors, a further analysis indicated that Configuration C provided the largest RT-CIT effect size,  $t(23) = 5.00$ ,  $p < .001$ ,  $d = 1.02$ ,  $MD = 18.1$ , similar to that typically reported in the literature (Suchotzki et al., 2017). In contrast, configurations A and B produced smaller, medium sized effects,  $t(25) = 3.03$ ,  $p = .006$ ,  $d = .594$ ,  $MD = 15.1$  and  $t(25) = 2.43$ ,  $p = .023$ ,  $d = .476$ ,  $MD = 10.2$  respectively. One possible reason for the smaller effect size with configuration B is it may have required large eye movements between the images given that they were presented on a monitor with a 16:9 aspect ratio oriented in portrait mode. This eye movement requirement might have added noise to the RT data. The general difficulty with configuration B is also evidenced by the increased error rates compared to the other configurations.

Configuration A was similar to configuration C with the exception that the images were larger and there was no gap between the fixation point and the bottom of the image. It is not obvious why this relatively small difference might have resulted in a smaller effect size. However, one possibility is that the larger images prompted more within-image exploratory eye movements which, as with configuration C, might have added noise to the RT responses. In contrast, the smaller images in configuration C might have been able to be ‘processed in a glance’ with less need for eye movements to be made. On this basis, even though there were no significant differences between the configurations, a consideration of effect sizes



indicated that configuration C would likely be the best choice for the remaining experiments.

Irrespective of configuration and of most interest, when collapsed over all the configurations, the RT-CIT effect was larger when stimuli were presented with a higher verticality, i.e. at the top of the screen, and this finding was not affected by the display configuration. The effect was driven primarily by slower RTs to crime items presented at the top of the screen. This result fits with previous work that has shown that negative and immoral stimuli (associations relevant to the crime item/lie response in this experiment) are recognized slower when they are presented on the top of the screen versus the bottom and vice versa ([Meier & Robinson, 2004](#); [Meier, Sellbom & Wygant, 2007](#)). However, based on previous verticality findings, it was also expected that control items, requiring a truthful (positive and moral) response, would be faster when presented on top of the screen versus the bottom – this was not found in this experiment. Finally, no effects were found for error rates, including no difference between control and crime items.

### Experiment 2: Vertical RT-CIT

In the previous experiment there was an effect of verticality in line with that predicted from the literature i.e. slower responses to the negative, immoral crime items when presented at the top of the screen. Given the novelty of this finding, the main aim of Experiment 2 was to attempt to replicate the verticality effect using the configuration from Experiment 1 that had produced the largest effect size (configuration C).

#### Method

Experiment 2 used the same methodology as Experiment 1 for configuration C with the exception that ISI was increased (500, 800 & 1000 to 750, 1000 & 1250) based on feedback from some participants who said that they found it particularly challenging. Therefore, this experiment had a 2 (Location: Top vs. Bottom) x 2 (Item: Control vs. Crime) two-way repeated measures design with RTs and error rates as dependent variables. A power analysis using G\*Power ([Faul, Erdfelder, Lang, & Buchner, 2007](#)), and the effect size between Item x Location from Experiment 1 ( $\eta_p^2 = .082$ , and  $\alpha = 0.05$  for a single group), suggested a minimum sample size of 26 participants would be sufficient for a power of 0.95. Twenty-seven participants (22 women), aged between 18-20 years ( $M = 18.7$ ,  $SD = .65$ ) were recruited through a University online participant panel at the author's institution. Participants received £3 payment for taking part in the 30-minute testing session.

## Results

### Reaction Times

No participants were removed due to error rates above 50%. Target item trials that exceeded the response deadline (1.5%), were faster than 200ms (0.4%) and incorrect trials (5.9%) were removed from the analysis – note, incorrect responses were used in the error analysis.

Mean RTs were analyzed using a 2 (Location: Top vs. Bottom) x 2 (Item: Control vs. Crime) two-way ANOVA. This revealed a significant main effect of: Item,  $F(1, 26) = 55.7, p < .001, MSE = 25710, \eta_p^2 = .682$ , overall RTs were slower to crime items compared to control items (see [Figure 7.4](#)) but not Location,  $F(1, 26) = 2.07, p = .163, MSE = 677, \eta_p^2 = .074$ . There was a significant two-way interaction between Location and Item,  $F(1, 26) = 17.9, p < .001, MSE = 4256, \eta_p^2 = .408$  which was driven by both slower reaction times to crime items presented on the top of the monitor compared to bottom,  $t(26) = 3.28, p = .003, d = .631, (MD = 17.6)$  and faster reaction times to control items presented on the top of the monitor compared to bottom,  $t(26) = 2.08, p = .048, d = .400, (MD = 7.55)$ . This resulted in the RT-CIT effect being larger for stimuli presented on top of the screen,  $t(26) = 9.13, p < .001, d = 1.76, (MD = 43.4)$  compared to the bottom,  $t(26) = 3.39, p = .002, d = .653, (MD = 18.3)$ .

### Error Rates

Overall error rates were low ( $M = 3.0\%, SD = 5.7$ ) and error rates were analyzed in the same way as the RTs. This revealed no significant effects of: Item,  $F(1, 26) = .149, p = .702, MSE = 2.03, \eta_p^2 = .006$ , Location,  $F(1, 26) = .960, p = .336, MSE = 2.69, \eta_p^2 = .036$ , or their interaction,  $F(1, 26) = .040, p = .843, MSE = .098, \eta_p^2 = .002$ .

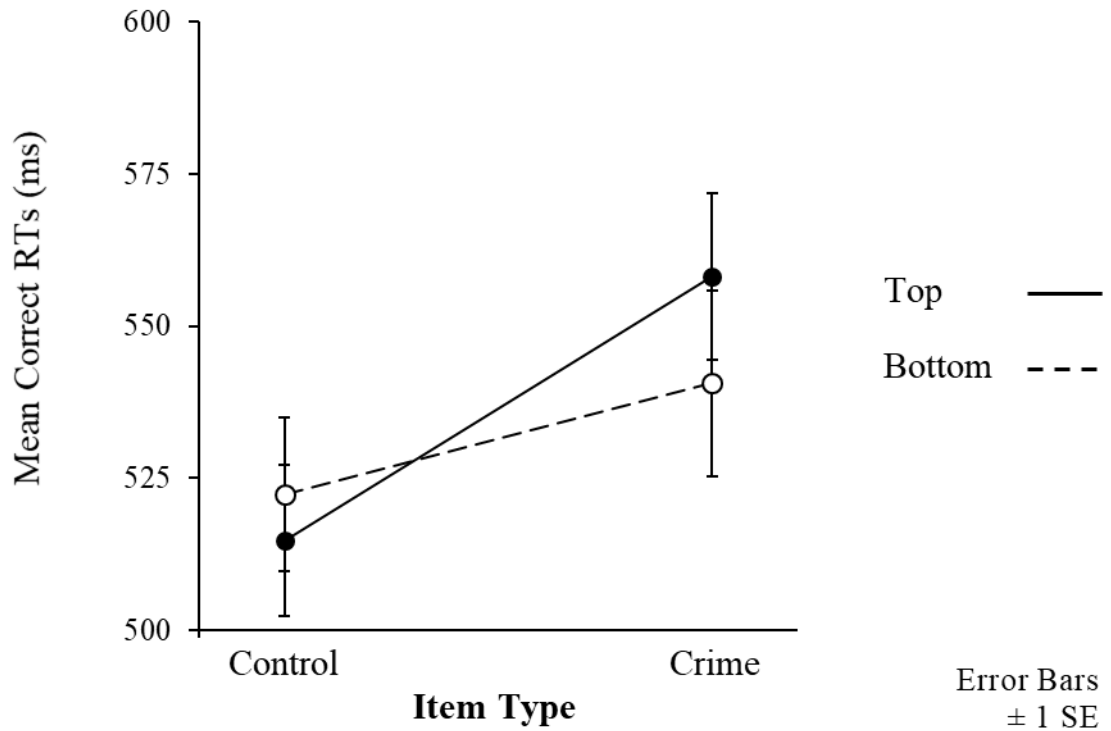


Figure 7.4. Experiment 2 - Mean correct RTs as a function of Item Type and Vertical position.

### Discussion

The main finding was a replication of the verticality effect found in Experiment 1 in which crime items presented at the top of the screen resulted in slower RTs than those presented at the bottom. Again, no effects were found on error rates. An additional finding was that RTs to control items were faster at the top of the screen compared to the bottom. This finding is also consistent with previous verticality research which has shown that as well as negative and immoral stimuli being recognized slower when they are presented at the top of the screen, positive stimuli are recognized faster at the top (Meier & Robinson, 2004; Meier, Sellbom & Wygant, 2007).

The combination of crime stimuli being responded to more slowly when presented at the top of the screen and control stimuli being faster at the bottom resulted in a very large RT-CIT effect ( $d = 1.76$ ) when items were presented at the

top of the screen compared to at the bottom ( $d = .653$ ). Accordingly, it would be interesting to determine whether the vertical RT-CIT presented here results in increased CIT detection rates. To test this however, innocent participants, unknowledgeable about the crime item, would need to be tested or simulated. Neither of these options were possible in this experiment for two reasons. First, the crime stimuli were autobiographic scenes of the participants' university campus which meant that no innocent equivalent was available at the author's institution. Furthermore, the author did not feel that innocent participants could be simulated given the standard methods for doing so are unproven for a vertical based RT-CIT. To solve this issue, participants could instead encode crime stimuli via a mock crime which innocent participants do not see. This would also increase the ecological validity of the RT deception test. This was the rationale for Experiment 3 in which a mock crime video was used to test both guilty and innocent participants before the vertical RT-CIT was administered.

### **Experiment 3: Vertical RT-CIT Mock Crime**

In the previous experiments in this Chapter the RT-CIT effect appeared to differ depending on where the stimuli were presented on the screen. Specifically, RTs to crime items were slowed when stimuli were presented at top the screen compared to the bottom (Experiment 1 and 2), and faster RTs for control items presented at the top of the screen (Experiment 2). This resulted in increased RT-CIT effects when stimuli were presented at spatially higher positions within the display. However, it was unclear as to any effect this might have on CIT detection rates when an innocent group of participants is considered. Accordingly, in Experiment 3, a mock crime paradigm was used so that the results from both guilty and innocent participants could be tested and compared using a vertical RT-CIT. As well as providing a further replication, a signal detection analysis could also be conducted to determine the detection rates of the vertical RT-CIT. Note that verticality is relative and therefore in a vertical RT-CIT, stimuli would need to be presented on the top and the bottom. Therefore, the signal detection analysis was conducted on all trials collapses over vertical position. This would establish whether having a larger CIT effect for stimuli on top, but smaller CIT effect for images on the bottom, results in an overall higher diagnosticity for the vertical RT-CIT

#### **Method**

The method was the same as Experiment 1 except that: i) guilty (knowledgeable about crime related details) and innocent participants were tested adding the factor of Suspect; ii) instead of University campus scenes, participants watched a mock crime video with innocent participants not watching a video and; iii) all participants were given an alibi statement containing images to remember (to act as targets).

### Participants

As established from the power analysis in Experiment 2, 26 is adequate to find an Item x Location interaction. However, to also find the effect that RTs to crime items presented on top are slower than the bottom, the effect size from Experiment 2 was used for an additional power analysis using G\*Power ( $d = .631$ , and  $\alpha = 0.05$  for a single group with a power of 0.95), which suggested that 34 participants would be required. Therefore, eighty-seven participants (47 women), aged between 18-38 years ( $M = 21.0$ ,  $SD = 3.1$ ) were recruited through a University online participant panel at the author's institution. Participants received £4 payment for taking part in the 40-minute testing session. Forty-five participants were assigned to the guilty condition and forty-two to the innocent.

### Mock Crime

Participants assigned guilty watched a 3-minute, 1<sup>st</sup> person perspective video where innocent participants did nothing. Participants were asked to “imagine as best as possible” that they were the person in the video carrying out the task. In the mock crime video (Figure 7.5) participants watched the culprit wandering around University Campus. The culprit came coming across a bike locked up outside the *Humanities building entrance* (crime items in italics and in Figure 7.6). The culprit covered up a nearby CCTV camera using *shaving foam* and then used some *bolt cutters* to break the bike lock. The culprit then met an accomplice *Mike* in a multi-story *carpark* to hand over the bike for cash.

### False Alibi

Following the video (or no video for innocent participants), ‘suspects’ were asked to imagine that they have been contacted by the police informing them that they are now a potential suspect in a recent crime and that they would now take a lie

detection test. The participant was then reminded to try to appear as innocent as possible and to deny any knowledge of the crime. Participants were then given an alibi to remember with five images that they would need to respond 'Yes' to (in the same fashion as the New York University scenes in Experiment 1). Their alibi statement was: *"It wasn't me who committed that crime as I was with my friend, Ryan at his home gardening all day. We only left his house to buy some garden clippers and weed killer from a nearby DIY store."* (Targets highlighted). From here the procedure did not differ from Experiment 1.



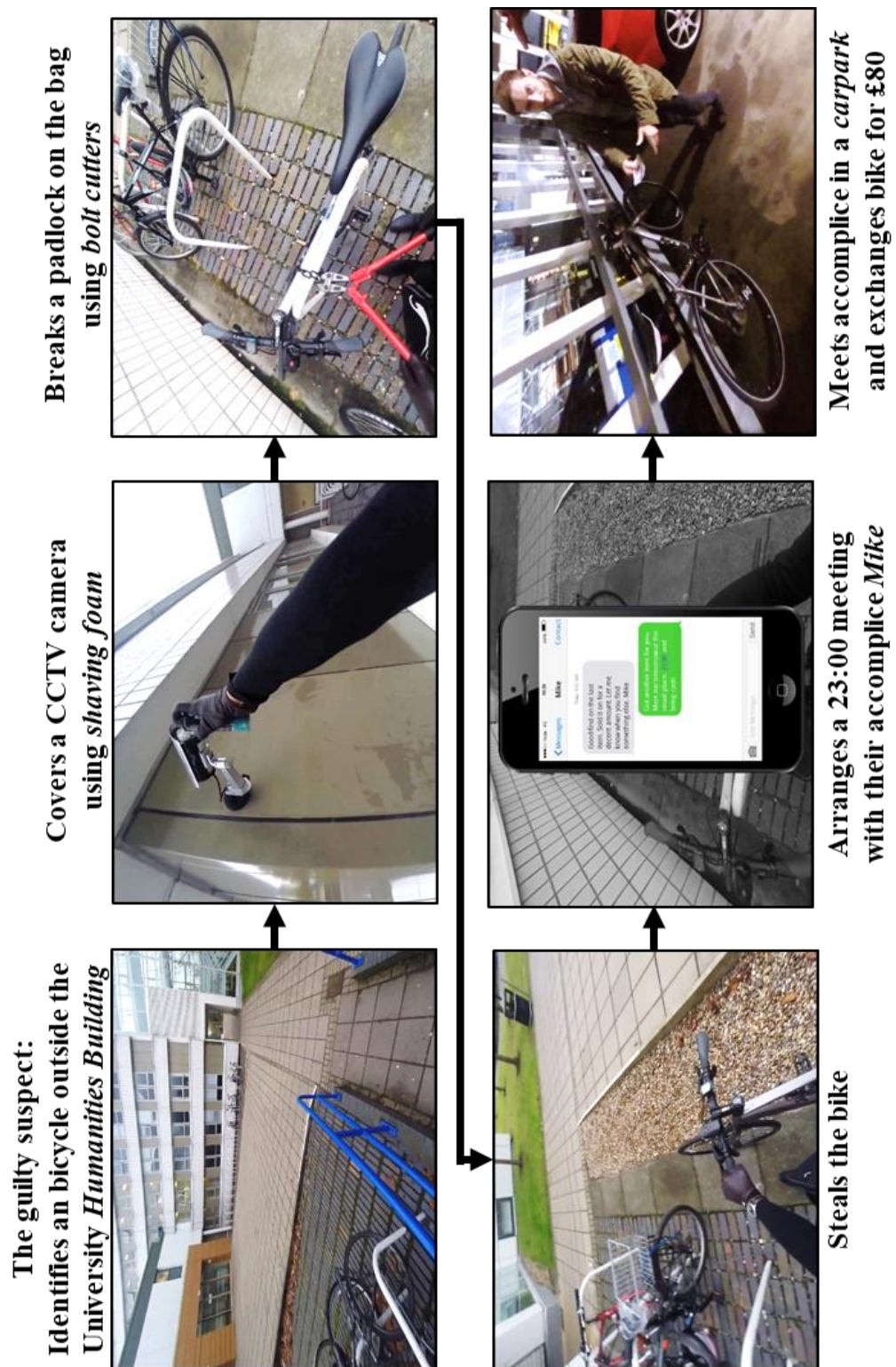


Figure 7.5. Key events in the 1<sup>st</sup> person-perspective mock crime video that guilty suspects view (*crime items in italics*).

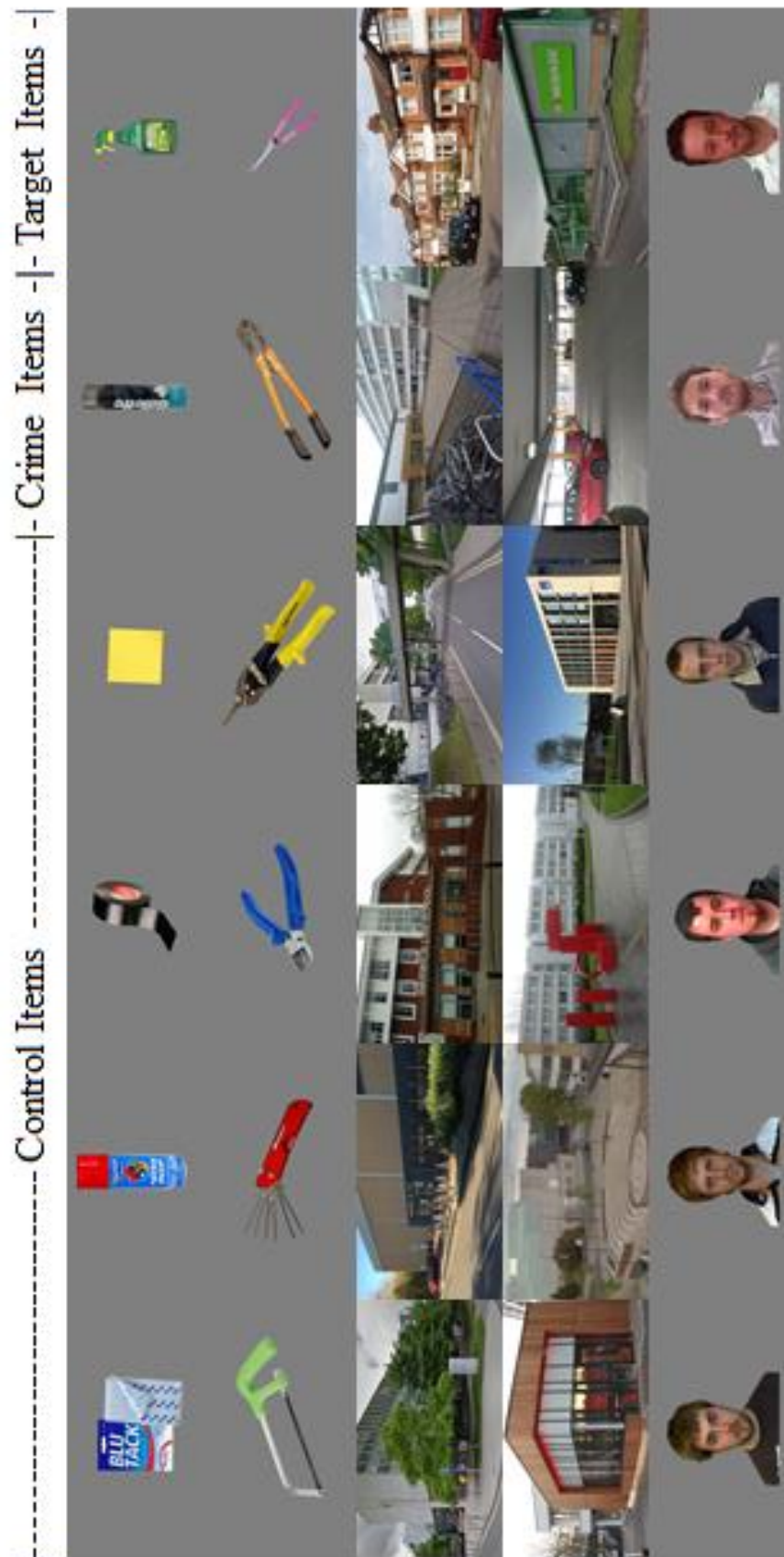


Figure 7.6. All CIT items used in Experiment 3.

## Results

### Reaction Times

Two participants in the guilty group were removed due to error rates above 50% (59% and 87%). Including target items, trials that exceeded the response deadline (1%), were faster than 200ms (0.4%) and incorrect trials (4.7%) were removed from the analysis – note, incorrect responses were used in the error analysis.

Mean RTs were analyzed using a 2 (Suspect: Guilty vs. Innocent) x 2 (Location: Top vs. Bottom) x 2 (Item: Control vs. Crime) three-way mixed ANOVA with Suspect as the between-subject factors. This revealed a significant main effect of: Item,  $F(1, 83) = 5.17, p = .026, MSE = 2221, \eta_p^2 = .059$ , overall RTs were slower to crime items compared to control items ([Figure 7.7](#)). There was no main effect of Location,  $F(1, 83) = .002, p = .965, MSE \approx 0, \eta_p^2 \approx 0$ ; or Suspect,  $F(1, 83) = .167, p = .684, MSE = 1171, \eta_p^2 = .002$ . There was a significant two-way interaction between: Location and Suspect,  $F(1, 83) = 32.0, p < .001, MSE = 10564, \eta_p^2 = .278$ , which was driven by guilty participants having slower RTs for stimuli at the top; and Item and Suspect,  $F(1, 83) = 43.9, p < .001, MSE = 18863, \eta_p^2 = .346$ , with RTs to crime items slower for guilty suspects. However, there was no two-way interaction between Location and Item,  $F(1, 83) = 2.92, p = .092, MSE = 464, \eta_p^2 = .034$ . Finally, there was a significant three-way interaction between Location, Item and Suspect,  $F(1, 83) = 11.8, p = .001, MSE = 1883, \eta_p^2 = .125$ .

Follow up 2-way ANOVAs were conducted separately for guilty and innocent suspects with mean RTs analyzed using x 2 (Location: Top vs. Bottom) x 2 (Item: Control vs. Crime) two-way ANOVA. For guilty suspects, there was a significant main effect of: Item,  $F(1, 42) = 26.1, p < .001, MSE = 17219, \eta_p^2 = .383$ , overall reaction times were slower to crime items compared to control items (see [Figure 7.7](#)),

and Location,  $F(1, 42) = 16.7, p < .001, MSE = 5428, \eta_p^2 = .285$ , overall reaction times were slower for items at top of the screen. There was a significant two-way interaction between: Location and Item,  $F(1, 42) = 9.01, p = .005, MSE = 2134, \eta_p^2 = .177$ , which was driven by slower RTs to crime items presented at the top of the monitor compared to the bottom,  $t(42) = 4.08, p < .001, d = .622, (MD = 18.3)$ .

Overall RTs did not differ when control items were presented on the top compared to the bottom,  $t(42) = 1.71, p = .094, d = .261, (MD = 4.19)$ . Finally, the RT-CIT effect was larger when stimuli were presented on the top,  $t(42) = 5.60, p < .001, d = .854, (MD = 27.1)$  compared to the bottom,  $t(42) = 3.03, p = .004, d = .462, (MD = 13.0)$ .

For innocent suspects, there was an unexpected significant main effect of: Item,  $F(1, 41) = 20.6, p < .001, MSE = 4021, \eta_p^2 = .335$  where overall RTs were slower to control items compared to crime items (see [Figure 7.7](#)), and Location,  $F(1, 41) = 15.2, p < .001, MSE = 5140, \eta_p^2 = .271$ , where overall RTs were slower for stimuli at the bottom of the screen. The Location x Item interaction was not significant,  $F(1, 41) = 2.96, p = .093, MSE = 236, \eta_p^2 = .067$ .

### Error Rates

Error rates were low overall ( $M = 0.9\%, SD = 2.9$ ) and were analyzed in the same way as for RTs. There were no significant main effects or interactions; Item,  $F(1, 82) = .087, p = .769, MSE = .127, \eta_p^2 = .001$ ; Location,  $F(1, 82) = .047, p = .830, MSE = .075, \eta_p^2 = .001$ ; Suspect,  $F(1, 82) = 1.61, p = .208, MSE = 66.1, \eta_p^2 = .019$ ; Location x Suspect,  $F(1, 82) = .287, p = .594, MSE = .461, \eta_p^2 = .003$ ; Location x Item,  $F(1, 82) = 1.72, p = .193, MSE = 5.32, \eta_p^2 = .021$ ; Item x Suspect,  $F(1, 82) = 4.35, p = .40, MSE = 6.35, \eta_p^2 = .050$ ; Location x Item x Suspect,  $F(1, 82) = .258, p = .613, MSE = .798, \eta_p^2 = .003$ .

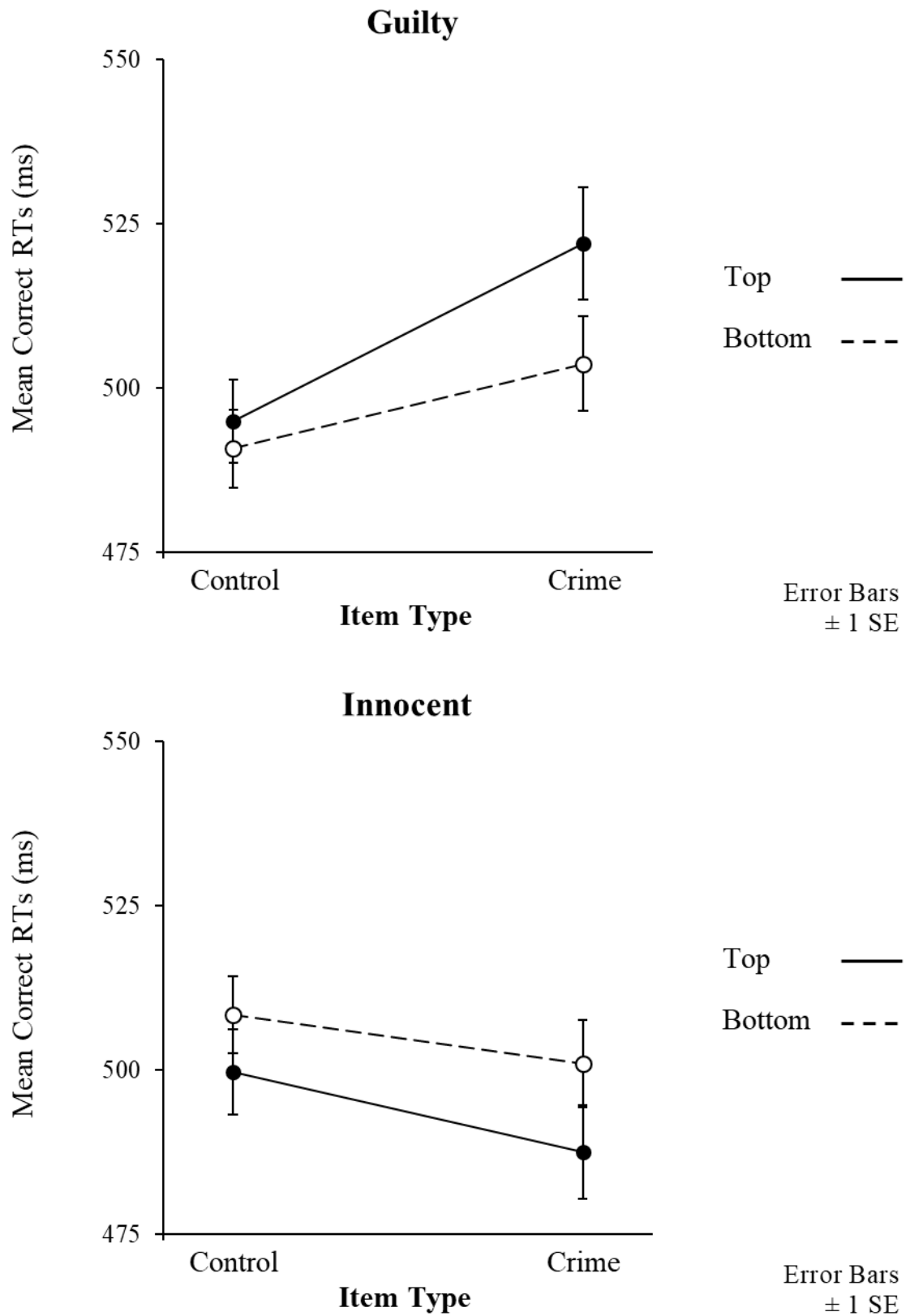
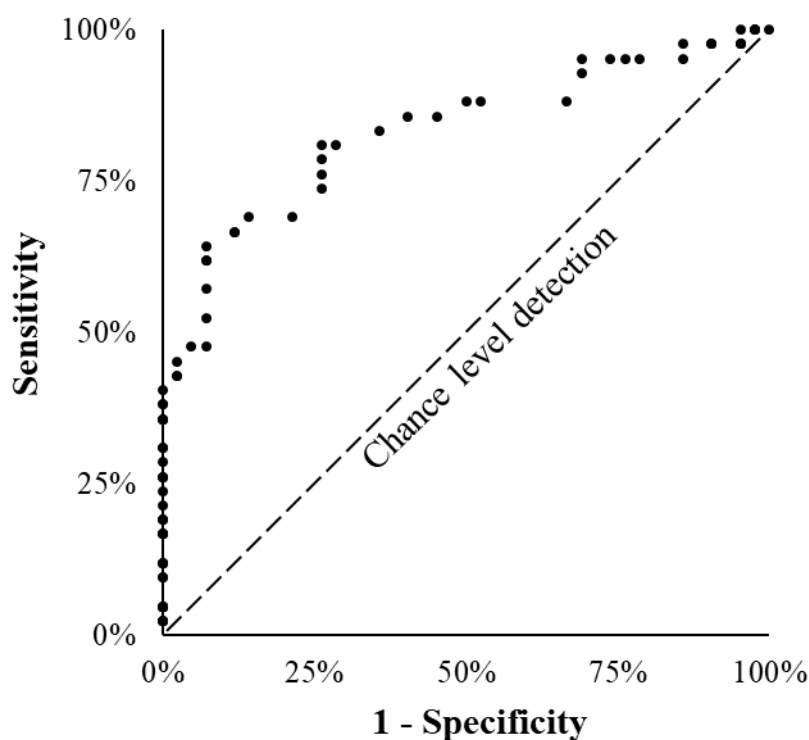


Figure 7.7. Experiment 2 - Mean correct RTs as a function of Item Type and Vertical position.

### Signal Detection Analysis

To assess the diagnosticity of the vertical RT-CIT, signal detection analysis was conducted to determine the degree of separation between the guilty and innocent participants. A Receiver Operator Curve (ROC) was generated using the RT-CIT effect data for both the ‘guilty’ and ‘innocent’ groups. As shown in [Figure 7.8](#), the vertical RT-CIT curve is closer to the upper left-hand corner of the graph, which indicates high overall accuracy ([Zweig & Campbell, 1993](#)). The area under this curve ( $AUC$ ) allows an objective measure of diagnosticity, the accuracy trade-off between the test sensitivity and specificity. An  $AUC$  of 0.5 suggests no discrimination, 0.7-0.8 is considered fair, 0.8-0.9 is excellent, and 0.9+ is outstanding ([Hosmer Jr, Lemeshow, & Sturdivant, 2000](#)). For the vertical RT-CIT,  $AUC = .831$ , indicating an excellent diagnostic test with a large effect size (Cohens’  $d = 1.38$ ).



*Figure 7.8. ROC curves showing CIT detection diagnosticity between guilty and innocent participants in a vertical RT-CIT.*



## Discussion

Following on from Experiments 1 and 2, in this experiment, mock crime stimuli and an innocent group were introduced to: i) increase ecological validity, ii) allow a signal detection analysis, iii) test any potential interactions of a vertical RT-CIT with innocent participants, iv) act as an additional replication. In Experiment 3, guilty participants were found to have slower RTs to crime items when presented on top of the screen compared to the bottom. This again resulted in a larger RT-CIT effect when stimuli were presented at the top, ( $d = .854$ ) compared to the bottom, ( $d = .462$ ). Again, no effects for error rates were found in this experiment suggesting that error rates may be of little use in the RT-CIT.

The verticality effect found for guilty participants in this experiment was similar to that found in Experiment 1. In both Experiment 1 and 3, RTs to crime items were slower when stimuli were presented at the top compared to the bottom, but no location-based difference was found for control items. This suggests that control items, which might have a more of a neutral association than a positive one, are not affected of vertical positioning. Therefore, the findings for Experiment 3 are partially in line with previous studies showing that negative and/or immoral stimuli are recognized slower when presented in a high relative position due to a mismatch of association where positive and good stimuli are preferred at the top ([Meier & Robinson, 2004](#); [Meier, Sellbom & Wygant, 2007](#)).

Interestingly, for innocent participants, RTs were significantly faster to crime items, compared to controls but with no vertical interaction. The lack of an interaction with verticality was not surprising as innocent participants do not know which stimuli are the crime items and therefore are not required to provide a deceptive response. Testing an innocent group allow confirmation that the verticality

effects were not simply due to guilty participants finding it more difficult to process stimuli presented on top. This explanation can be rejected however, as innocent participants actually processed top stimuli faster than bottom. So why then did innocent participants respond to crime items faster (the opposite of the RT-CIT effect) compared to control items? One reason may be that, despite every effort to ensure that crime and control items were matched, the crime images may have still be easier to process than controls due to differences in image complexity (e.g. features in a scene). As can be seen in [Figure 7.6](#), the images were stimuli in category i.e. the matched controls for the bolt cutter crime image were similar tools with the same function. Furthermore, these same stimuli had been tested with innocent participants in previous physiological CIT experiments in this thesis; no such crime and control difference were found then. Possibly then, it may be more difficult to adequately match control items in the RT-CIT such that the difference between crime and control items is negligible. This might be an issue simulating innocent participant data for the RT-CIT (e.g. [Carmel, Dayan, Naveh, Raveh, & Ben-Shakhar, 2003](#)) and therefore further work should follow this up.

Finally, overall, the vertical CIT had excellent diagnosticity ( $AUC = .831$ ) with a large effect size ( $d = 1.38$ ) between guilty and innocent participants. This suggested that even when the CIT for stimuli on the bottom is compromised (due to a congruency of placing crime items at the bottom), overall diagnosticity is high due to the benefit of presenting crime stimuli on top. Clearly, as verticality is relative, i.e. there needs to be a top and a bottom, conducting an RT-CIT where stimuli are always presented on top is unlikely to generate a verticality effect. One option is to only analyze stimuli presented on top and in this experiment, doing so gives a larger effect size and detection ( $AUC = .892$ ,  $d = 1.60$ ).



### General Discussion

The RT-CIT aims to detect deception by revealing the response inhibition experienced by lying participants who respond deceptively to crime related stimuli (Verschuere, Suchotzki, & Debey, 2014). Although response inhibition appears to be the primary cognitive function driving the RT-CIT effect (difference in RTs between crime and control stimuli), others have been shown to be important such as working memory, task switching and valence (Debey et al., 2015; Suchotzki et al., 2017; Ambach, Stark & Vaitl, 2011; Hu et al., 2013; Debey, Verschuere & Crombez, 2012; Varga et al., 2015).

In the current study, the effects of verticality (relative positioning of stimuli in the vertical dimension) were explored in the RT-CIT. Verticality has been linked to various metaphoric associations such high/up equating to positive/moral whereas low/down equals negative/immoral (Cian, 2017; Meier et al., 2007; Crawford et al., 2006; Meier, Sellbom & Wygant, 2007). In the RT-CIT, guilty participants respond deceptively to crime stimuli whilst responding truthfully to control stimuli. For guilty participants, then, crime items can be considered negative and require an immoral response with, arguably, the opposite true for control items which receive truthful responses. Based on previous findings of vertical metaphors, it was predicted that placing crime items at the top of the screen, where positive/moral stimuli are expected, would result in slower responses due to an incongruence compared to when crime items are presented on the bottom. For stimuli placed at the top of the screen this would result in an increased RT-CIT effect as this verticality effect is in the same direction as response inhibition, i.e. slower responding crime items but even more so when they are presented on top. Overall, the results from this study supported this prediction.

Verticality had not been manipulated in the RT-CIT previously and therefore it was unknown whether it would reduce or negate the RT-CIT effect as participants would have the additional task of searching for stimulus (top or bottom). Therefore, in Experiment 1, three different display configurations were used to investigate the potential effect of verticality. Only one configuration from Experiment 1 was found to generate a large overall RT-CIT effect and therefore this configuration (configuration C) was used for the following two experiments. Ignoring the different display configurations, the results from Experiment 1 showed that RTs to crime stimuli were slower when the crime stimuli were presented at the top of the screen compared to the bottom. This result was also found in Experiments 2 and 3 and suggests that participants take longer to respond deceptively to negative stimuli when those stimuli are presented high. In Experiment 3, the verticality effect did not affect innocent participants presumably as they do not associate negativity with their responses to crime stimuli as they do not know they are the crime stimuli and do not respond deceptively to them.

In addition to the finding that RTs slow to crime items presented high, Experiment 2 also found that control items, responded to truthfully, were processed faster on the top due to a congruency effect. These findings together more fully align with those of previous verticality studies ([Cian, 2017](#)). However, this was not found in Experiments 1 and 3 suggesting that control items might also be considered as neutral items rather than a positive and hence do not benefit from vertical associations.

As innocent participants were included in Experiment 3, a signal detection analysis could be conducted which showed that RT-CIT effect size and corresponding detection was high. It would be interesting to compare a vertical RT-

CIT with the standard approach to determine whether there is any benefit to detection.

The overall conclusion is that metaphorical associations of verticality in deception i.e. up is congruent with truth but incongruent with lies, can be used to increase RT-based deception detection.

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## CHAPTER 8

**Mega-analysis:****Self-reported motivation, stress, performance and countermeasure  
use in picture-based concealed information tests****Abstract**

Extracting and/or verifying information from uncooperative human sources is an important security task. Concealed Information Tests (CIT) can detect whether suspects recognize critical and privileged information and are widely applied in Japanese criminal investigations. Presented is a mega-analysis of twenty CIT experiments conducted by the authors. Participants took part in either physiological ( $n = 646$ ) or reaction time ( $n = 504$ ) image-based CITs where they were motivated to conceal recognition of objects, scenes and faces encoded either autobiographically, in a mock crime, or by viewing crime videos. Following CITs, many participants ( $n = 754$ ) self-reported their; motivation to avoid detection, stress, perceived performance; and whether they attempted countermeasures. Motivation, stress and countermeasure use did not significantly impact the CIT however, participants that believed they performed well (i.e. avoided detection), tended not to. CIT responses were equivalent across image stimulus types (objects, scenes or faces). Overall, CIT diagnosticity was high for reaction time and skin conductance measures ( $AUC = .891$  and  $AUC = .792$  respectively) although lower for heart rate ( $AUC = .708$ ). Findings presented add to the existing literature suggesting that the CIT is a robust and diagnostic memory detection technique with potential applications for intelligence gathering.



## Introduction

The Concealed Information Test (CIT) is a memory detection technique for determining whether someone recognizes specific details relating to a crime. Previous meta-analysis studies have shown that CIT detection can be moderated by various factors including, but not limited to: motivation to avoid detection; verbal deceptive responses; the use of countermeasures; the number of crime items presented; the CIT measure used; and whether innocent participants were tested or simulated (Meijer, Selle, Elber & Ben-Shakhar, 2014; Ben-Shakhar & Elaad, 2003; Suchotzki, Verschuere, Van Bockstaele, Ben-Shakhar & Crombez, 2017). Combining all data collected throughout this thesis ( $n = 1150$ ), potential moderators are explored for both physiological CITs (skin conductance/heart rate) and reaction time CITs (RT-CIT). The moderators explored were: self-reported motivation to beat the CIT by avoiding detection; self-reported stress felt during the CIT; self-reported perceived CIT performance (aka self-assessed lying ability); self-reported countermeasure use and type; picture stimulus type (objects, scenes or faces); and impact of simulated vs. tested innocent participant. Finally, the overall diagnosticity of picture-based CITs is reported.

Various deception studies have found that increased motivation by the deceiver to avoid detection produces decreased deception performance - this is termed the motivation impairment effect (see Bond Jr & DePaulo, 2006; DePaulo, Lanier & Davis, 1983). For the CIT, increased motivation increased CIT detection (Ben-Shakhar & Elaad, 2003; Meijer et al., 2014). In previous CIT studies, motivation was manipulated by either: i) telling participants that only those with high intelligence and self-control can avoid detection; ii) promising an incentive to avoid detection; or iii) suggestion of a punishment if they are detected (Meijer et al., 2014).

In this thesis participants were often incentivized with the offer to receive their ‘lie detection score’ (their normalized mean CIT effect) with a cash prize for the top scoring participant(s) in that study. Given there was little variance in the amount participants were incentivized with in this thesis, the effect of motivation based on incentives could not be considered in this mega-analysis. Instead, self-reported motivation to avoid detection was measured (Likert scale 1<sub>low</sub> - 6<sub>high</sub>) after each participant underwent a CIT. Self-reported motivation has been frequently used in areas such as education research and is considered a valid measure of task motivation (Fulmer & Frijters, 2009). Self-reported motivation may in fact be a more reliable motivation measure as it can account for differences in participants’ intrinsic and extrinsic motivation.

Participants were also asked to rate their performance at appearing innocent/avoiding detection (Likert scale 1<sub>low</sub> - 6<sub>high</sub>), with previous research suggesting that self-assessment ratings can be another indicator of overall effort and task motivation (Trope, 1982). A recent meta-analysis concluded that although people tend to rate their own deception detection skills as high, they rate their lying abilities as low (Elaad, 2018). In the only study where the effect of self-reported deception abilities was tested in the CIT, participants were asked to rate their lie detecting ability and lying ability both before and after the CIT which was conducted several days after a mock crime (Elaad & Sommerfield, 2016). The results showed that the SCR CIT effect was larger for guilty participants who rated their lie abilities as high, compared to those that rated them low. It was suggested that this may be due to different levels of motivation to avoid detection, as participants that believed they were good liars may have felt more motivated to prove so in the CIT. Further work

on this topic was recommended by Elaad (2018), particularly in relation to correlating motivation with perceived performance.

Emotional arousal, or stress does not appear to impact CIT responding (Ben-Shakhar & Nahari, 2018). However, only a few studies have directly tested this, with stress manipulated by suggestions of a punishment if detected, much like the manipulations for motivation (Bradley & Janisse, 1981; Kugelmass & Lieblich, 1966). To the author's knowledge, self-reported stress during the CIT has not yet been considered and is likely to relate to both self-reported motivation and performance. Self-reported stress may also relate to how nervous a participant felt during the CIT, which is believed to increase the rate of false positives in the comparison question polygraph test, where physiological responses are used to detect deception (Fienberg et al., 2003).

Countermeasures are any attempts, mental or physical, to alter the outcome of the CIT. Countermeasures have been found to be effective at reducing CIT detection for SCR measures but less so for parasympathetic measures like respiration (Ben-Shakhar & Nahari, 2018). Very few studies have tested the impact of countermeasures in the RT-CIT (refer back to Experiment 3, Chapter 2 for review), however, overall those that have, appear to find no impact on detection (Suchotzki et al., 2017). Typically, in CIT studies which test the effects of countermeasure strategies, instructions are provided by the experimenter as to exactly what countermeasure the participants should attempt. In this thesis no such instruction was given (except for Experiment 3, Chapter 2) and instead participants were simply asked an open question whether they tried any strategy to beat the CIT. For analysis purposes, the qualitative countermeasure responses were grouped into eight types: None (no countermeasure); Attended to controls; Slow breathing; Stay calm; Slow

heart rate; Covert movement; Suppressing memory; Think about something else; and any RT-based countermeasure (for the RT-CIT exclusively).

A CIT should be designed so that all stimuli within each question are equally plausible and salient to an unknowledgeable innocent participant. If this requirement is met then participants should respond equally to all stimuli, crime or control item. This property of the CIT means that an innocent participant's data can be mathematically simulated by randomly drawing numbers from a standard normal distribution for each trial in the CIT (Meijer, Smulders, Johnston & Merckelbach, 2007). A recent meta-analysis found that studies that used an innocent group reported higher detection rates ( $d = 1.64$ ) compared to those that simulated innocent participants ( $d = 1.39$ ) suggesting simulation is a more conservative measure (Meijer et al., 2014). Throughout this thesis both methods of generating data of innocent participants were used and therefore a comparison of the CIT effect for both approaches could be made.

Few studies present CIT stimuli as pictures, with many instead using audible or text stimuli (Ambach, Bursch, Stark & Vaitl, 2010). Previous work that has been conducted on presentation modality has found no significant difference between CIT detection (SCR and heart rate) for picture versus text stimuli (Ambach et al., 2010). As picture stimuli were used throughout this thesis, this provided an opportunity to report and contrast CIT effect sizes with the literature to determine the effectiveness of CIT picture stimuli. Based on memory research findings, such as the picture superiority effect, and encoding specificity (review Chapter 5 for a discussion), it was reasonable to predict that the CIT effects in this thesis may be larger than those found previously where pictures are rarely used (Meijer et al., 2014). To the author's knowledge, the type of picture stimuli (objects, scenes and faces) have not been

investigated except in Chapter 2 of this thesis. In Chapter 2 the RT-CIT effect for both scene and object stimuli were found to produce detection rates, despite previous evidence that these scenes and objects are processed differently in the brain ([Oliva & Torralba, 2006](#)). Given scene, object and face picture stimuli were used within subjects throughout this thesis, this factor could also be explored.

The use of mega-analyses within an author's own work has been recommended as an effective way to explore effects that may be small as well as reporting well powered effects with reduced confidence intervals ([Goh, Hall & Rosenthal, 2016](#)). Here, specifically it allows the analysis of self-reported measures collected across multiple experiments that could not otherwise have been meaningfully explored.

## Method

Across the 20 experiments (2 pilot) in this thesis, a total of 1150 participants (704 women and 14 not disclosing), aged between 18 - 51 years ( $Mean = 20.7$ ,  $SD = 3.6$ ) were recruited (Table 8.1). Ignoring the manipulations in each experiment, all participants took part in either an RT-CIT ( $n = 504$ ) or a physiological-based CIT ( $n = 646$ ) administered by one of eleven experimenters. ‘Guilty’ participants ( $n = 960$ ) carried out one of eight mock crime scenarios presented either as: 1<sup>st</sup> person perspective videos (five different videos); real-world tasks (two different tasks); or, as autobiographic images of University campus. In eight of these experiments, crime details used in the CIT were categorized as objects, scenes or faces - picture stimuli were used in all experiments conducted in this thesis. Finally, the same post-CIT questionnaire was used in 13 of these experiments ( $n = 754$ ) which provided a measure of self-reported: motivation to appear innocent ( $1_{low} - 6_{high}$ ); stress during the CIT ( $1_{low} - 6_{high}$ ); perceived CIT performance ( $1_{low} - 6_{high}$ ); countermeasure (if any) used (an open question later coded as one of eight countermeasure types (*None*, *RT-based Countermeasure* (RT-CIT exclusively), *Attended to controls*, *Slow breathing*, *Stay calm*, *Slow heart rate*, *Covert movement*, *‘Suppressing’ memory*, and *Think about something else*)).

Specific participant information, methodologies and procedures for the previously reported 18 experiments can be found in Chapters 2-7 with a summary provided in Table 1. Therefore, in this chapter, only a short recap of the methodologies used is provided below and in Table 8.2. Following this, participant information and methodologies for a two additional pilot experiments, not previously described in the thesis, are reported below.

Table 8.1. Number of experiments and participants used in this analysis

| Experiment        |                                     |         |        |          | Number of Participants |          |       | Stimuli                   |                          |                         | Other          |                |                           |
|-------------------|-------------------------------------|---------|--------|----------|------------------------|----------|-------|---------------------------|--------------------------|-------------------------|----------------|----------------|---------------------------|
| CH                | Study                               | Exp No. | Exp ID | CIT Type | Guilty                 | Innocent | Total | Self-reports <sup>1</sup> | CIT Stimuli <sup>2</sup> | Mock Crime <sup>3</sup> | M <sup>4</sup> | R <sup>5</sup> | CIT Examiner <sup>6</sup> |
| 2                 | Scenes                              | 1       | A      |          | 36                     | -        | 36    | N                         | S                        | 7 (A)                   | 0              | 1              | 1                         |
|                   |                                     | 2       | B      | RT       | 44                     | -        | 44    | Y                         | O, S                     | 4 (V)                   | 1              | 1              | 1                         |
|                   |                                     | 3       | C      |          | 98                     | -        | 98    | N                         | S                        | 7 (A)                   | 0              | 1              | 10                        |
| 3                 | Shared Knowledge and Paired Testing | 1       | D      | SCR, HR  | 32                     | -        | 32    | Y                         | O, S, F                  | 2a (V)                  | 1              | 0              | 1                         |
|                   |                                     | 2       | E      |          | 64                     | -        | 64    | Y                         |                          | 2bc (V)                 | 1              | 0              | 1                         |
|                   |                                     | 3       | F      |          | 84                     | -        | 84    | Y                         |                          | 2bc (V)                 | 1              | 0              | 1                         |
|                   |                                     | 4       | G      | 30       | -                      | 30       | N     | S                         | 7 (A)                    | 1                       | 1              | 1              |                           |
|                   |                                     | 5       | H      | RT       | 40                     | -        | 40    | N                         | S                        | 7 (A)                   | 1              | 1              | 11                        |
|                   |                                     | 6       | I      |          | 64                     | -        | 64    | Y                         | O, S, F                  | 2 (V)                   | 1              | 1              | 5                         |
| 4                 | Investigator Influence              | 1       | J      | SCR,     | 36                     | 36       | 72    | Y                         | O, S, F                  | 1 (V)                   | 1              | 1              | 2-3                       |
|                   |                                     | 2       | K      | HR       | 40                     | 40       | 80    | Y                         |                          |                         | 1              | 1              | 4-5                       |
| 5                 | Virtual Reality                     | 1       | L      | SCR, HR  | 64                     | 64       | 128   | Y                         | O, S                     | 5 (R)                   | 1              | 1              | 1                         |
| 6                 | Fading Memories                     | 1       | M      | SCR      | 44                     | -        | 44    | Y                         | O, S                     | 6 (R)                   | 1              | 1              | 1 <sup>8</sup>            |
|                   |                                     | P       | N      | SCR      | 43                     | -        | 43    | Y                         | O, S, F                  | 1 (V)                   | 1              | 1              | 8-9                       |
|                   |                                     | 2       | O      | SCR, HR  | 40                     | -        | 40    | Y                         | O, S, F                  | 1 (V)                   | 1              | 1              | 6-7                       |
| 7                 | Verticality                         | 1       | P      |          | 78                     | -        | 78    | N                         | S                        | 7 (A)                   | 0              | 1              | 1                         |
|                   |                                     | 2       | Q      | RT       | 28                     | -        | 28    | N                         | S                        | 7 (A)                   | 0              | 1              | 1                         |
|                   |                                     | 3       | R      |          | 45                     | 42       | 87    | N                         | O, S, F                  | 4 (V)                   | 1              | 1              | 1                         |
| 8                 | Pilot Studies <sup>7</sup>          | P       | S      | SCR,     | 40                     | -        | 40    | Y                         | S                        | 7 (A)                   | 1              | 1              | 1                         |
|                   |                                     | P       | T      | HR       | 11                     | 10       | 21    | Y                         | O, S, F                  | 2a (V)                  | 1              | 1              | 1                         |
| Physiology CIT    |                                     |         |        |          | 498                    | 150      | 648   |                           |                          |                         |                |                |                           |
| Reaction-Time CIT |                                     |         |        |          | 463                    | 42       | 505   |                           |                          |                         |                |                |                           |
| Total             |                                     |         |        |          | 961                    | 192      | 1153  |                           |                          |                         |                |                |                           |

<sup>1</sup>Self-reported motivation, stress, perceived performance and countermeasures<sup>2</sup>Picture stimuli type; O = Object stimuli, S = Scene stimuli and F = Face stimuli<sup>3</sup>V = Mock crime videos (1-4), R = 'real' mock crimes (5-6) and A = autobiographic scenes of University (7)<sup>4</sup>M: 1 = Motivated with incentive to remain undetected, 0 = No motivation beyond payment<sup>5</sup>R: 1 = Verbal deceptive response "no" required, 0 = Silent deceptive response required "no"<sup>6</sup>Experimenter that conducted the CIT (1 = Author, 2-11 research assistants under supervision)<sup>7</sup>Two pilot experiments were included in the mega-analysis that were not described in previous chapters<sup>8</sup>The mock crime phase of this experiment was administered by another PhD student. See Sukumar, Wade and Hodgson, (2018) for details

Table 8.2. CIT structure and exclusions for experiments used in this study

| Experiment |                                     |         |        | CIT Structure |          |           |          |         |                             | Exclusions                  |                      |               |                 |                             |
|------------|-------------------------------------|---------|--------|---------------|----------|-----------|----------|---------|-----------------------------|-----------------------------|----------------------|---------------|-----------------|-----------------------------|
| CH         | Study                               | Exp No. | Exp ID | CIT type      | No. CITs | CIT ratio | CIT reps | ISI (s) | Image time <sup>1</sup> (s) | ECG window <sup>2</sup> (s) | SCR NRs <sup>3</sup> | Signal errors | RT errors > 50% | Trials removed <sup>4</sup> |
| 2          | Scenes                              | 1       | A      |               | 5        | 1:4       | 15       | 0.5-1.5 | 0.8                         | -                           | -                    | -             | 0               | -                           |
|            |                                     | 2       | B      | RT            | 4        | 1:4       | 15       | 0.5-1.5 | 0.8                         | -                           | -                    | -             | 0               | -                           |
|            |                                     | 3       | C      |               | 5        | 1:4       | 15       | 0.5-1.5 | 0.8                         | -                           | -                    | -             | 3               | -                           |
| 3          | Shared Knowledge and Paired Testing | 1       | D      | SCR, ΔHR      | 9        | 1:4       | 1        | 10      | 5                           | 15                          | 3                    | 0             | -               | 0.6%                        |
|            |                                     | 2       | E      |               | 6        | 1:4       | 1        | 10      | 5                           | 15                          | 3                    | 5             | -               | 0.8%                        |
|            |                                     | 3       | F      |               | 6        | 1:4       | 1        | 10      | 5                           | 15                          | 11                   | 1             | -               | 0.3%                        |
|            |                                     | 4       | G      | 5             | 1:4      | 15        | 0.5-1.5  | 0.8     | -                           | -                           | -                    | 2             | -               |                             |
|            |                                     | 5       | H      | RT            | 5        | 1:4       | 15       | 0.5-1.5 | 0.8                         | -                           | -                    | -             | 0               | -                           |
|            |                                     | 6       | I      |               | 6        | 1:4       | 15       | 0.5-1.5 | 0.8                         | -                           | -                    | -             | 0               | -                           |
| 4          | Investigator Influence              | 1       | J      | SCR, ΔHR      | 8        | 1:4       | 1        | 9       | 4                           | 15                          | 3                    | 1             | -               | 0.75%                       |
|            |                                     | 2       | K      | ΔHR           | 8        | 1:4       | 1        | 12      | 6                           | 18                          | 3                    | 0             | -               | 0.23%                       |
| 5          | Virtual Reality                     | 1       | L      | SCR, ΔHR      | 4        | 1:3       | 2        | 10      | 5                           | 15                          | 5                    | 2             | -               | 0.5%                        |
| 6          | Fading Memories                     | 1       | M      | SCR           | 5        | 1:4       | 2        | 4       | 4                           | -                           | 5                    | 0             | -               | -                           |
|            |                                     | P       | N      | SCR           | 6        | 1:4       | 2        | 9       | 4                           | -                           | 8                    | 0             | -               | -                           |
|            |                                     | 2       | O      | SCR, ΔHR      | 6        | 1:4       | 2        | 9       | 5                           | 14                          | 4                    | 3             | -               | 0.81%                       |
| 7          | Verticality                         | 1       | P      |               | 5        | 1:4       | 15       | 0.5-1.5 | 0.8                         | -                           | -                    | -             | 1               | -                           |
|            |                                     | 2       | Q      | RT            | 5        | 1:4       | 15       | 0.5-1.5 | 0.8                         | -                           | -                    | -             | 0               | -                           |
|            |                                     | 3       | R      |               | 4        | 1:4       | 15       | 0.5-1.5 | 0.8                         | -                           | -                    | -             | 2               | -                           |
| 8          | Pilot Studies <sup>5</sup>          | P       | S      | SCR, ΔHR      | 5        | 1:4       | 1        | 10      | 5                           | 15                          | 1                    | 0             | -               | -                           |
|            |                                     | P       | T      | ΔHR           | 9        | 1:4       | 1        | 10      | 5                           | 15                          | 0                    | 0             | -               | -                           |

<sup>1</sup>Duration that the CIT stimuli were presented for<sup>2</sup>The window used for processing the ECG data<sup>3</sup>Number of SCR non-responders (standard deviation < 0.01)<sup>4</sup>Total percentage of trials removed due to large movements<sup>5</sup>Two pilot experiments were included in the mega-analysis that were not described in previous chapters



### **General Procedure**

The procedure, mock crime stimuli, CIT tests and data processing were similar for all experiments in this thesis. For completeness this section provides a reminder of the general methodology used in this thesis. If the reader does not wish to review this then please read on from the *Pilot Experiments Included section* below.

In all cases participants were provided with an overview of the study including their right to withdraw, given the opportunity to ask any questions, and invited to provide consent and demographic information. Participants allocated to a 'Guilty' condition would then carry out a mock crime either as a real-world task, through watching a video or through imagining using autobiographic information. Participants allocated to the 'Innocent' condition (if present) would either do nothing or be given a video of similar length to the guilty suspect but where no crime was committed. All participants were then asked to imagine that they had been contacted by the authorities informing them that they were suspects in a recent crime and would therefore undertake a lie detection test. They were all reminded to try and appear as innocent as possible by simply denying any knowledge of the crime. The experimenter would then explain what had happened in the crime without disclosing any of the specific crime items and ask the participants if they knew anything else about the crime. Participants were then allowed to preview all the CIT questions and items (unlabeled) whilst the CIT procedure was explained, and a short practice given. In physiological CITs, the experimenter then connected any required sensors. Participants would then take the CIT either separately or with a partner (see below).

### All Mock Crimes

The five mock crime videos used in eleven experiments (see [Table 8.1](#)) were filmed and watched either in 2D or 3D active stereo from a 1<sup>st</sup> person perspective. Participants were instructed to imagine that they carried out the activities of the mock crime culprit's perspective. Crime details in the videos were then used in the CIT (crime items in italics below). In two experiments, instead of watching a video, participants carried out a mock crime in the 'real-world'. Finally, in seven experiments participants simply pretended not to recognize photographs of memorable University campus scenes.

**Real-world task 1.** Participants in the guilty condition carried out a mock crime at the authors' institution in which they entered an *office*, identified an unattended *handbag* and stole a *tablet* computer before handing it over to an 'accomplice' in a *common room*.

**Real-world task 2.** Participants were instructed to enter a University *bookshop*, find a black *waist bag* placed on top of a yellow and white *box*, and steal a *wallet* inside this bag. They returned this wallet to the experimenter at the University *cinema*.

**Autobiographic Information.** Crime details were photographs of memorable University campus scenes; landscapes, buildings, and other structures.

**Mock Crime Video 1.** The culprit began by wondering around a University building before encountering an empty *lecture theatre* with an unattended bag inside. They entered the room, masked a CCTV camera using *shaving foam* and then identified that the bag was padlocked. Using *bolt cutters*, the culprit opened the bag to find a *laptop* inside which they then stole. The culprit sends a text message to their accomplice *Mike*, which said to meet at 22:00 to exchange the stolen laptop. They

then met Mike in a multi-story *carpark* and exchanged the laptop for £60 cash.

Participants assigned to the innocent condition also watched a 1<sup>st</sup> person perspective video but instead of committing a crime they instead walked around a town.

**Mock Crime Video 2a, 2b and 2c.** Three separate, but overlapping in content, videos (2a, 2b and 2c) were used in five experiments. Videos 2a and 2b started with an onscreen planning stage where both suspects, whilst viewing the heist plans, were phoned by a superior, *Mike*, whose picture was displayed on a phone on screen. They were told about the theft they would be about to conduct, which involved breaking into a secret lab, stealing a prototype hologram device and related files before passing it onto Mike. The suspect then added their tools to their bag before leaving to join their partner outside the target lab. Starting just outside the secret *lab*, both suspects forced open the lab door using a *crowbar* before disabling an alarm system. After this, the suspects separated into a different area within the facility where they could not see what the other was doing and hence would be obtaining exclusive information. In video 2a, suspect A used some *shaving foam* to cover up a CCTV camera before breaking a padlock with some *bolt cutters* to access the prototype device which they then stowed in their bag. In video 2b, Suspect B accessed an adjacent room which had a copy of the device *blueprints* on the wall which they then photographed. Moving into a connected *office* the suspect then accessed a password protected computer by correctly interacting with an image password of a *brain hologram* before then stealing some files related to the device before they then met with Suspect A to leave. After this, in video 2a, suspect A met with Mike alone in a multi-story *carpark* to hand over the stolen items. Video 2c contained the scenes from both video 2a and 2b and was used to assess the suitability of the crime details as CIT stimuli.

**Mock Crime Video 3.** The suspect identified a locked bike outside the *Humanities building entrance*. The participants covered up a nearby CCTV camera using *shaving foam* and then used some *bolt cutters* to break the bike lock. The culprit then met an accomplice in a multi-story *carpark* to hand over the bike for cash.

### All CITs

**Physiological CIT.** Skin conductance responses (SCRs), and often heart rate change ( $\Delta HR$ ), were measured using wired electrodes attached to their fingers, wrist and ankle. During the CIT test phase, the participant would see between four and nine CIT blocks (*CIT No*, Table 8.2) presented in a random order, with each block beginning with a question e.g. “*Was this tool used to break the lock?*” followed by four to five (*CIT ratio*, Table 8.2) CIT items presented sequentially as images e.g. *bolt cutters* typically on a monitor (although in three experiments stimuli were sometimes presented either as physical photographs or using a virtual reality headset). Out of these CIT items, one directly related to the mock crime that the guilty participants had conducted (the crime item) and the remaining did not (control items). These crime items were presented for four to six seconds (*Image time*, Table 8.2) before disappearing to leave a blank screen for four to twelve seconds before the next CIT item (*ISI*, Table 8.2). Each CIT block was presented once or twice (*CIT reps*, Table 8.2) before the end of the CIT phase. The first CIT item presented in each block was a control item used to absorb the initial orienting to that item group and therefore excluded from all analysis. Participants were instructed to either verbally respond with ‘no’ in response to each item or to simply think the word ‘no’.

**RT-CIT.** The RT-CIT experiments conducted in this thesis were structurally similar to the physiological CIT but with some key differences. Rather than

presenting the CIT items within discrete blocks that relate to the same question and item type, in the RT-CIT all items are presented randomly within one large block with a broader question such as “*Does this relate to the crime?*”. Items within each block were presented sequentially in a random order with the constraint that two crime items could not occur consecutively. The CIT items were presented for a short duration (*Image time*, [Table 8.2](#)) of 800ms with a randomly selected inter-stimulus interval of either 500, 750 or 1500ms (*ISI*, [Table 8.2](#)). Participants simply responded “no” using a designated keyboard key within the image duration. For guilty participants, responding ‘no’ was a lie when presented with crime items. To ensure attention to all items, participants also had to respond ‘yes’ using a different key to target items which were randomly presented within each block – these responses did not require analysis. Responses from participants with error rates (i.e. pressing “Yes” to a crime items or “No” to the target items) above 50% were removed from further analysis as it is unlikely that they were following the task instructions (*RT Errors* >50%, [Table 8.2](#)) Responses faster than 200ms or slower than 800ms were also removed. RT-CIT experiments in this thesis used four to six (*CIT No*, [Table 8.2](#)) crime items each with four control items (*CIT ratio*, [Table 8.2](#)) and a target item in each block. Blocks were repeated fifteen times (*CIT reps*, [Table 8.2](#)) resulting in 360 – 540 trials.

### Post-CIT Questionnaire

After the CIT, participants were given a paper-based questionnaire consisting of multiple-choice questions to check that they had remembered the crime items if guilty. If they were innocent, they were asked to guess what they thought the crime detail might have been. Participants were also asked to rate using a Likert scale from 1<sub>low</sub> – 6<sub>high</sub>, their motivation to appear innocent during the CIT, their stress during the

CIT, how well they think they appeared innocent and where relevant, how immersive they found the mock crime scenario. Participants were also asked to provide an open answer to the question: *“Did you do anything to try and fool the polygraph test? If you did or didn’t please bullet point below – either case is fine.”* Finally, participants were debriefed.

### **Data Processing**

The data were processed in the same way with the same exclusion criteria for all physiological CIT experiments (see [Chapter 3](#) for example) and all RT-CIT experiments (see [Chapter 2](#) for example). For physiological CITs, the processing only differed in the window size used for averaging the heart rate data which depended on the CIT ISI used ([Table 8.2](#)). For all experiments, the number of participants and trials excluded from analysis are also detailed in [Table 8.2](#). Note that it was not possible to remove large movement errors in the: Faded Memories study ([Chapter 5](#)); Stimuli Onset Pilot (see footnote in [Chapter 5](#)); Physiological Scenes Pilot; and Unobtrusive measures Pilot, as synced physiology-video monitoring was not used.

### **Pilot Experiments Included**

#### **Pilot 1: Scene Stimuli Physiology CIT**

This experiment was conducted to assess the suitability of scene stimuli however, in this experiment the physiological (SCR and  $\Delta$ HR) CIT was used instead of the RT-CIT. This was conducted to confirm that scene stimuli elicited a similar CIT effect to that found in the literature with objects so that scene stimuli could be used in the other experiments reported in this thesis.

The CIT procedure was similar to that used in Experiment 1, Chapter 3 with the mock crime stimuli being scene images of Warwick University that participants

had to conceal knowledge of (same procedure described in Experiment 1, Chapter 2). Details of the CIT structure can be found in [Tables 8.1](#) and [8.2](#). Forty self-selected participants (24 women), aged between 18 - 34 years ( $M = 20.4$ ,  $SD = 2.8$ ) signed up to take part using an online participant panel at the author's institution. Participants received £5 payment for partaking in the 30-minute testing session and had the opportunity to receive their 'lie detection score' as well as a chance to win a £10 Amazon voucher if they obtained the lowest 'lie detection score'.

### **Pilot 2: Unobtrusive Physiological Measures**

This pilot experiment was aimed at measuring the CIT effect for multiple measures simultaneously in order to establish the effectiveness of contactless measures. As well as traditional CIT measures (SCR,  $\Delta HR$ , respiration and peripheral vasodilation), a high specification thermal imaging camera, eye tracker, high specification microphone and high definition camera were synced together with the CIT stimulus program to measure periorbital skin temperature, pupil dilation, voice stress and facial actions respectively. However, following this pilot experiment it was decided to postpone this study to a future date. Therefore, for the purpose of this mega-analysis only SCR and  $\Delta HR$  were processed and included.

The mock crime stimuli, procedure and CIT used was the same as Experiment 1, Chapter 3 with the exception of the multiple measures (see also [Tables 8.1](#) and [8.2](#)). Twenty-one self-selected participants (14 women), aged between 18 - 25 years ( $M = 20.2$ ,  $SD = 1.5$ ) from the author's institution received £8 payment for partaking in a 50-minute testing session, had the opportunity to receive their 'lie detection score' and a chance to win a £20 Amazon voucher if they obtained the lowest 'lie detection score'.

### **Planned Analysis**

Self-reported measures taken in thirteen experiments (Experiment with IDs; B, D, E, F, I, J, K, L, M, N, O, S and T) in this thesis were analyzed using a one-way ANOVA for each CIT measure (SCR,  $\Delta$ HR and RT). These measures were self-reported (Likert scale rating 1<sub>low</sub> – 6<sub>high</sub>) ‘motivation to beat the CIT’ ( $n = 754$ ), ‘stress during the CIT’ ( $n = 754$ ) and ‘perceived CIT performance’ ( $n = 754$ ). Self-reported countermeasure use, Yes vs. No ( $n = 808$ ) and the type of countermeasure were analyzed using a Contingency table and one-way ANOVA respectively. Countermeasure type, asked as an open question, was categorized as either: None ( $n = 277$ ), Attended to controls ( $n = 18$ ), Slow breathing ( $n = 81$ ), Stay calm ( $n = 15$ ), Slow heart rate ( $n = 14$ ), Covert movement ( $n = 7$ ), ‘Suppressing’ memory ( $n = 8$ ), Think about something else ( $n = 38$ ) and for the RT-CIT only, RT-based countermeasures ( $n = 103$ ).

Where participants saw object, face and scene picture stimuli, CIT effects for SCR and  $\Delta$ HR were analyzed using a one-way ANOVA comparing the stimuli type. As all CITs in this thesis used picture stimuli, CIT effects and diagnosticity are reported for SCR,  $\Delta$ HR and RTs using Cohen’s  $d$  and signal detection analysis. Finally, using one-way ANOVAs, the CIT effects of guilty, innocent and simulated innocents are compared to determine any bias in using simulated innocent groups to report CIT detection.



## Results

### Self-reported Measures

**Innocents vs. Guilty.** Compared to innocent participants, guilty participants self-reported: higher motivation,  $t(752) = 2.20, p = .028, d = .202, MD = .199$ ; more stress,  $t(752) = 7.25, p < .001, d = .665, MD = .895$ ; expected lower performance,  $t(752) = 8.94, p < .001, d = .820, MD = .991$ ; and used more countermeasures,  $\chi^2(1, N = 808) = 62.1, p < .001$  – 4.7% of innocent participants vs. 38.1% of guilty used countermeasures.

**Relationships between variables.** For guilty participants, self-reported perceived performance was found to: positively correlate with motivation,  $r(606) = .151, p = .001$ ; and negatively correlate with stress,  $r(606) = .107, p = .009$ ; with no correlation between motivation and stress,  $r(606) = .019, p = .642$ . Motivation ratings were marginally higher when guilty participants reported using some form of countermeasure,  $t(708) = 1.70, p = .090, d = .139, MD = .137$  (Table 8.3). However, neither stress nor perceived performance ratings differed between guilty participants who used countermeasures or not,  $t(708) = 3.06, p = .002, d = .251, MD = .340$  and  $t(708) = 1.65, p = .100, d = .135, MD = .174$ .

Table 8.3. Descriptive data for self-reported measures recorded in this thesis

| Self-reported measures        | Suspect  | N   | Mean / % | SD   |
|-------------------------------|----------|-----|----------|------|
| Motivation to avoid detection | Guilty   | 606 | 4.87     | 0.99 |
|                               | Innocent | 148 | 4.68     | 0.96 |
| Stress during the CIT         | Guilty   | 606 | 3.21     | 1.38 |
|                               | Innocent | 148 | 2.31     | 1.19 |
| Perceived Performance         | Guilty   | 606 | 3.41     | 1.19 |
|                               | Innocent | 148 | 4.40     | 1.30 |
| Countermeasure use            | Guilty   | 660 | 39%      | -    |

**Self-reported Motivation.** Guilty participant's mean normalized SCR,  $\Delta$ HR and RT-CIT effects were analyzed using a one-way ANOVA for Motivation level ( $1_{\text{low}} - 6_{\text{high}}$ ) – note that no responses were rated as 1 (Figure 8.1). For SCRs, this revealed no significant effect of Motivation,  $F(5, 452) = .495, p = .780, MSE = .078, \eta_p^2 = .005$ . For  $\Delta$ HR, there was no significant effect of Motivation,  $F(5, 434) = .792, p = .556, MSE = .106, \eta_p^2 = .009$ . For RTs, there was also no effect of Motivation,  $F(4, 103) = 1.04, p = .392, MSE = .036, \eta_p^2 = .039$ . These findings suggest that participants' self-reported motivation to avoid detection did not relate to their actual performance as measured using the CIT effect.

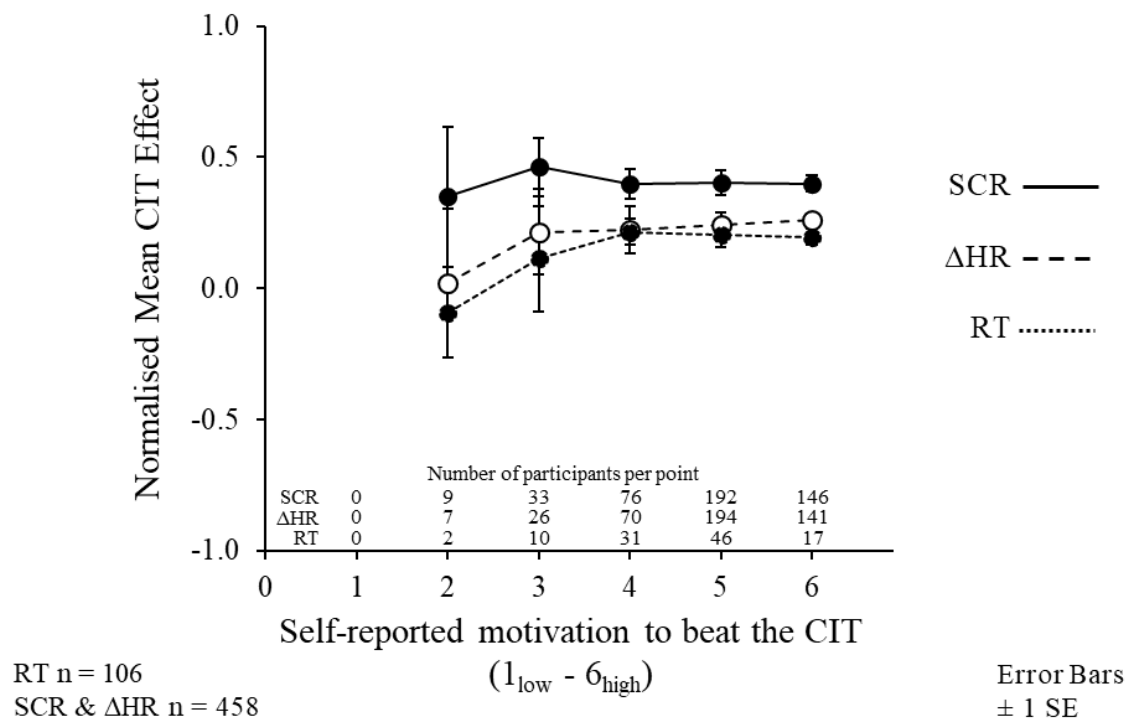


Figure 8.1. Normalized Mean CIT effect for SCR,  $\Delta$ HR and RTs as a function of self-reported motivation to appear innocent ( $1_{\text{low}} - 6_{\text{high}}$ ).

**Self-reported Stress.** Guilty participants' mean normalized SCR,  $\Delta$ HR and RT-CIT effects were analyzed using a one-way ANOVA for Stress level ( $1_{\text{low}} - 6_{\text{high}}$ ) (Figure 8.2). There was no significant effect of Stress for SCR,  $F(5, 452) = 1.15$ ,  $p = .333$ ,  $MSE = .179$ ,  $\eta_p^2 = .013$ ;  $\Delta$ HR,  $F(5, 434) = .249$ ,  $p = .940$ ,  $MSE = .034$ ,  $\eta_p^2 = .003$ , or RTs,  $F(5, 102) = .860$ ,  $p = .511$ ,  $MSE = .030$ ,  $\eta_p^2 = .040$ .

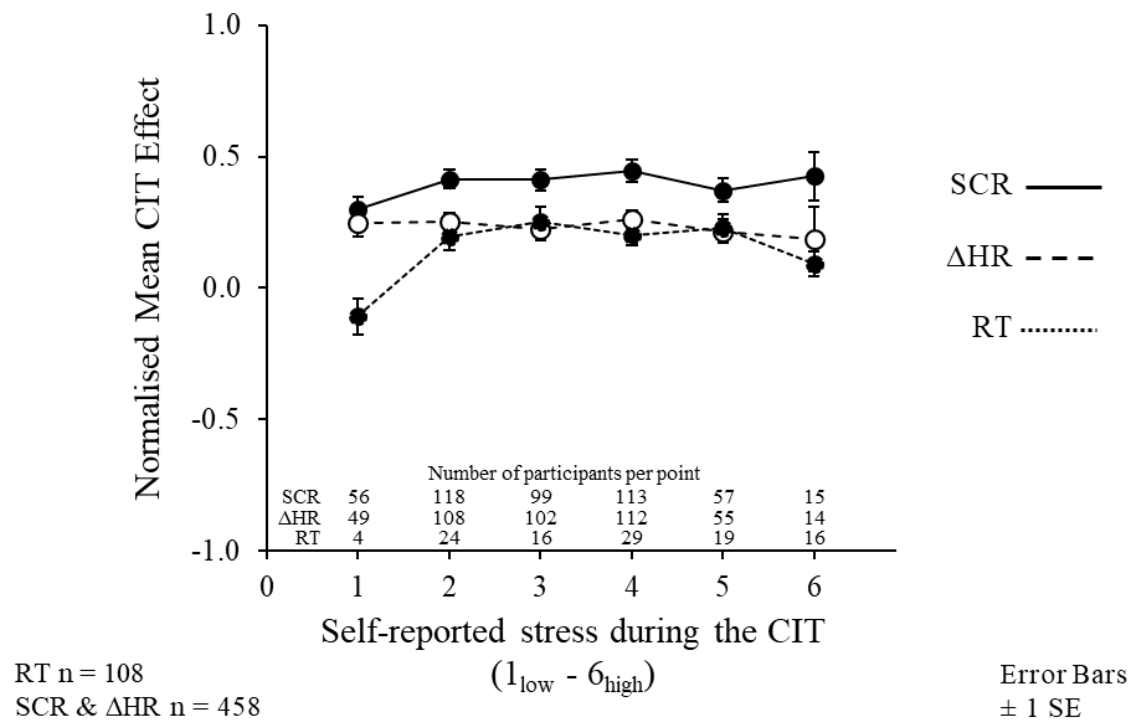


Figure 8.2. Normalized Mean CIT effect for SCR,  $\Delta$ HR and RTs as a function of self-reported stress during the CIT ( $1_{\text{low}} - 6_{\text{high}}$ ).

**Self-reported Performance.** Guilty participants' mean normalized SCR,  $\Delta$ HR and RT-CIT effects were analyzed using a one-way ANOVA for Perceived Performance level ( $1_{\text{low}} - 6_{\text{high}}$ ) (Figure 8.3). For SCR, this revealed a significant effect of Perceived CIT Performance,  $F(5, 452) = 2.26, p = .048, MSE = .347, \eta_p^2 = .024$ . Pairwise comparisons revealed significant difference between levels: 1-2 and 4-5 ( $p = .043, p = .049$  respectively). However, when Bonferroni corrected, no pairwise comparisons were significant. For  $\Delta$ HR and RTs, there was no significant effect of Perceived CIT Performance,  $F(5, 434) = 1.69, p = .135, MSE = .224, \eta_p^2 = .019$  and  $F(5, 102) = 1.01, p = .415, MSE = .035, \eta_p^2 = .047$  respectively. These findings suggest that participants who felt they had performed either poorly or very well on the CIT did not perform well as measured by their SCR CIT effect.

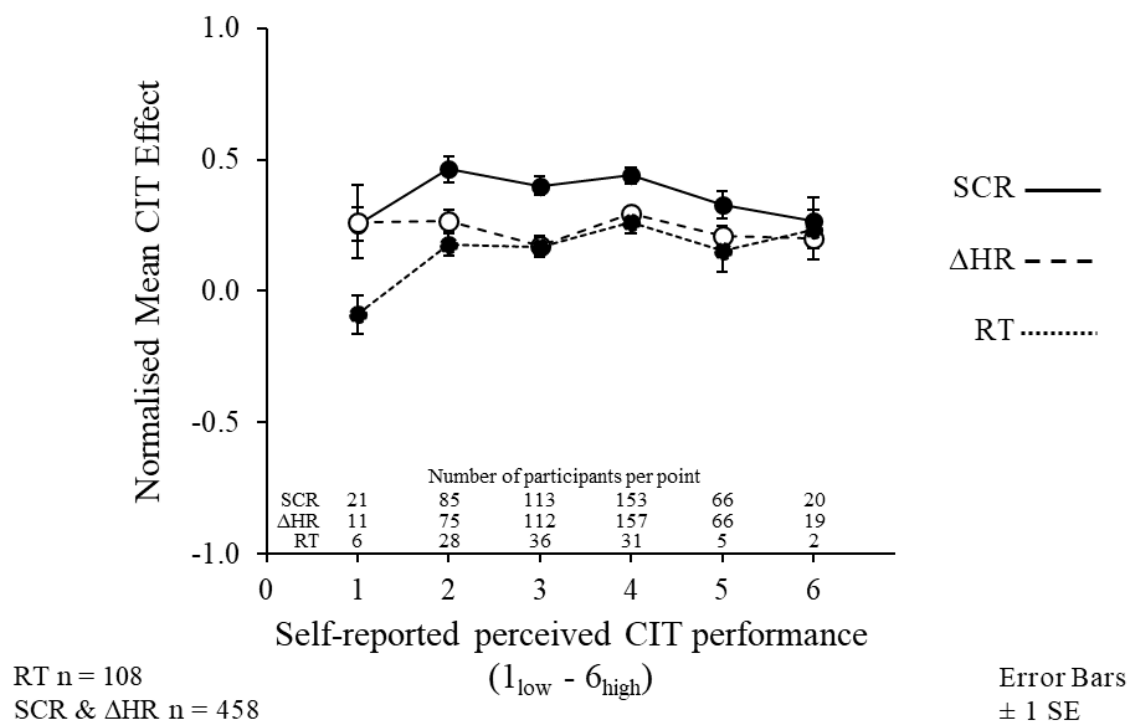


Figure 8.3. Normalized Mean CIT effect for SCR,  $\Delta$ HR and RT as a function of self-reported perceived performance ( $1_{\text{low}} - 6_{\text{high}}$ ).

**Self-reported Countermeasures.** Guilty participants' mean normalized SCR,  $\Delta$ HR and reaction time CIT effects were analyzed using a one-way ANOVA for each Countermeasure Type (None vs. Attended to controls vs. Slow breathing vs. Stay calm vs. Slow heart rate vs. Covert movement vs. Suppressing memory vs. Think about something else) (Figure 8.4). For SCR and  $\Delta$ HR, this revealed no significant effect of Countermeasure Type,  $F(7, 450) = 1.34, p = .229, MSE = .208, \eta_p^2 = .020$  and  $F(7, 432) = .932, p = .481, MSE = .125, \eta_p^2 = .015$  respectively.

Only 59 participants reported trying some form of countermeasure in the RT-CIT experiments. Of these, 48 were instructed to press their toe for control items (see Experiment 3, Chapter 2), 4 made “random RTs”, 4 “tried to keep RTs consistent”, 1 “slowed all responses”, 1 “responded faster to crime items” and 1 “made intentional errors”. Given the lack of variation and relatively small sample per countermeasure type, countermeasure use for all RT-CIT experiments were simply categorized as either yes (the participant attempted some countermeasure) or no (participants did not attempt any countermeasures). Therefore, participant’s mean normalized RT-CIT effects were analyzed using a t-test Countermeasure use (Yes vs. No) which revealed no effect of countermeasure use,  $t(159) = .614, p = .540, MD = .020$ .

Finally, mean normalized SCR and  $\Delta$ HR CIT effects were analyzed using a t-test (Countermeasure use, Yes vs. No) which revealed no effect of using a countermeasure on both SCR,  $t(456) = .856, p = .392, d = .082, MD = .032$  and  $\Delta$ HR,  $t(438) = .275, p = .783, d = .027, MD = .010$ . These findings suggest that the CIT effect was not influenced by whether participants chose to attempt a countermeasure strategy or not and that this was not moderated by the type of countermeasure attempted.

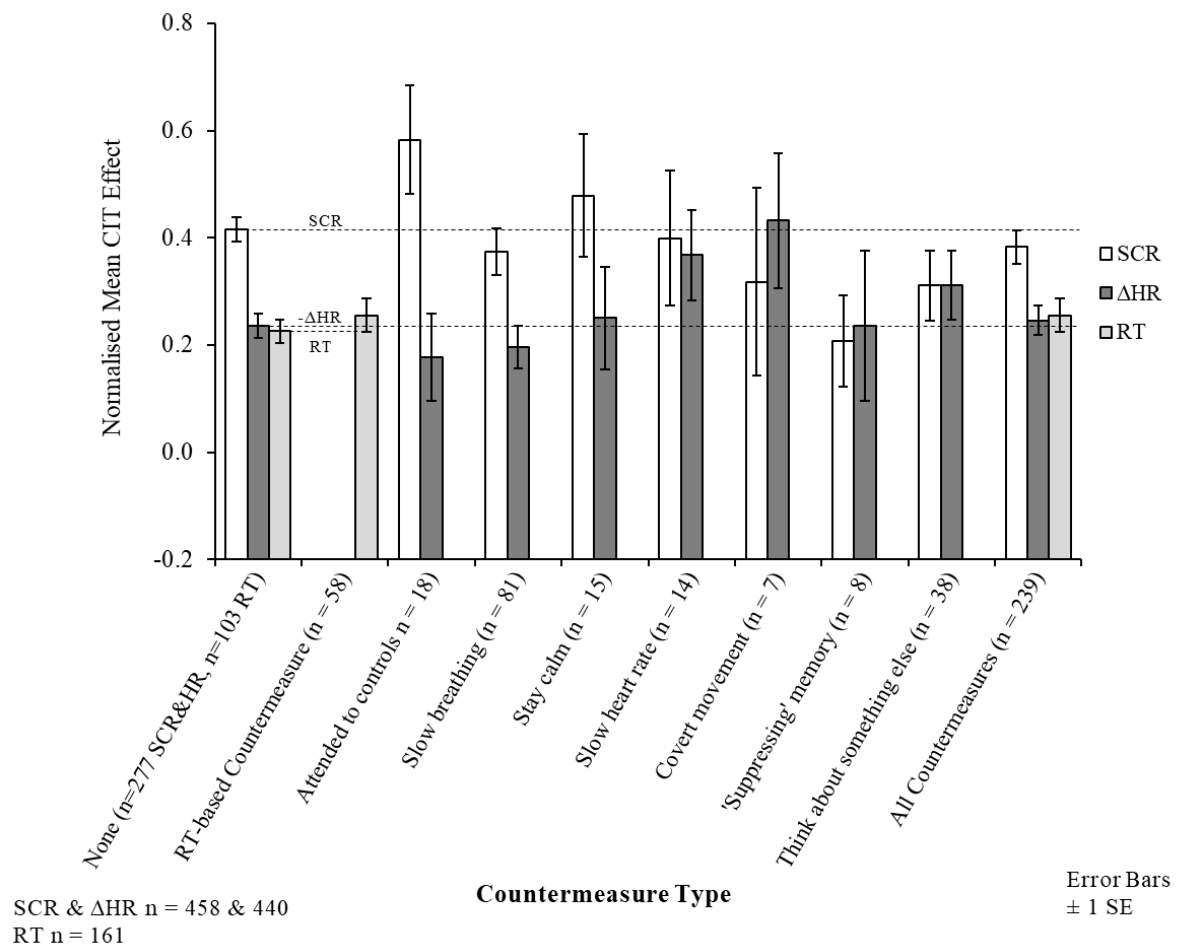


Figure 8.4. Normalized Mean CIT effect for SCR, ΔHR and RTs as a function of self-reported, and author categorized, countermeasure employed during the CIT.

### Stimulus Type

Guilty participants' mean normalized SCR and  $\Delta$ HR CIT effects were analyzed using a one-way ANOVA for each Stimulus type (Objects vs. Scenes vs. Faces) (Figure 8.5). For SCR and  $\Delta$ HR, this revealed no significant effect of Stimuli Type,  $F(2, 595) = 1.87, p = .156, MSE = 1.81, \eta_p^2 = .006$  and  $F(2, 614) = .504, p = .604, MSE = .271, \eta_p^2 = .002$  respectively. These findings suggest that the type of picture stimuli used does not impact the CIT effect for either SCR or  $\Delta$ HR.

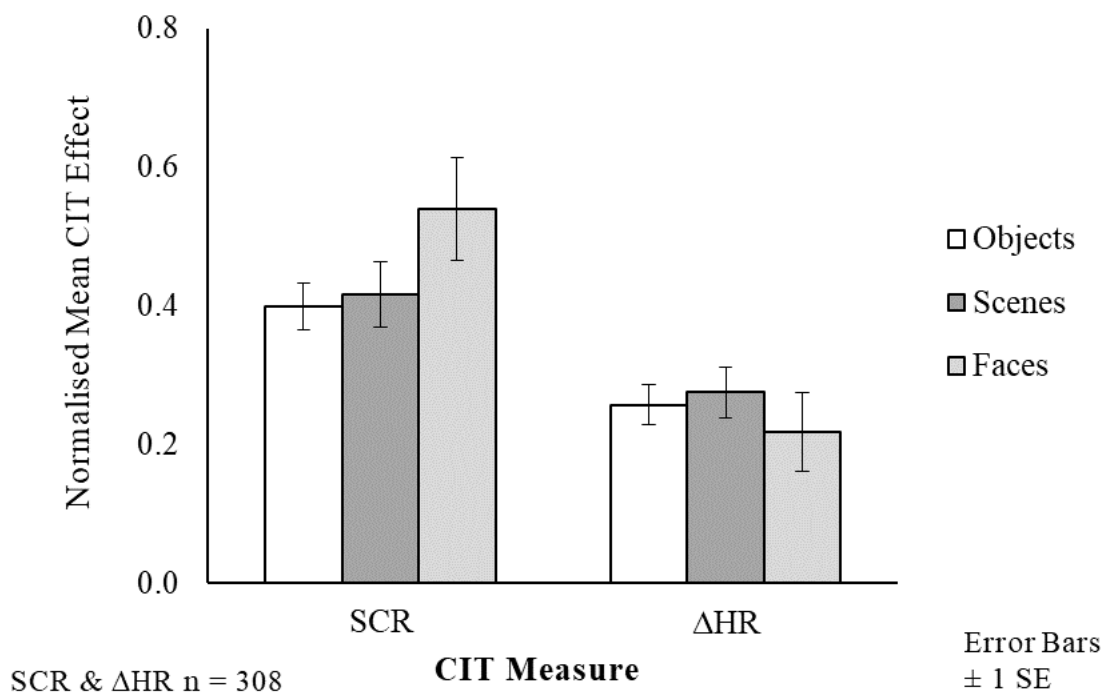


Figure 8.5. Normalized Mean CIT effect for SCR and  $\Delta$ HR as a function stimuli type.

### Picture-based CIT Diagnosticity

A Receiver Operator Curve (ROC) was generated for both the ‘guilty’ and ‘innocent’ (not simulated) groups for SCR,  $\Delta$ HR and RTs (Figure 8.7). For SCRs the  $AUC$  was .792 ( $d = 1.15$ ), indicating an excellent diagnostic test (Hosmer Jr, Lemeshow, & Sturdivant, 2013); for heart rate deceleration the  $AUC$  was .708 ( $d = .765$ ), indicating a good diagnostic test and; for RTs the  $AUC$  was .891 ( $d = 1.61$ ), indicating an excellent diagnostic test. The detection rate for SCRs were significantly better than heart rate deceleration, ( $AUC\ diff = .084$ ,  $SE = .036$ ,  $z = 2.34$ ,  $p = .019$ ) with reaction times being significantly better than SCRs, ( $AUC\ diff = .100$ ,  $SE = .041$ ,  $z = 2.40$ ,  $p = .016$ ). Individual effect sizes and  $AUC$ s for each experiment are provided in Table 8.6.

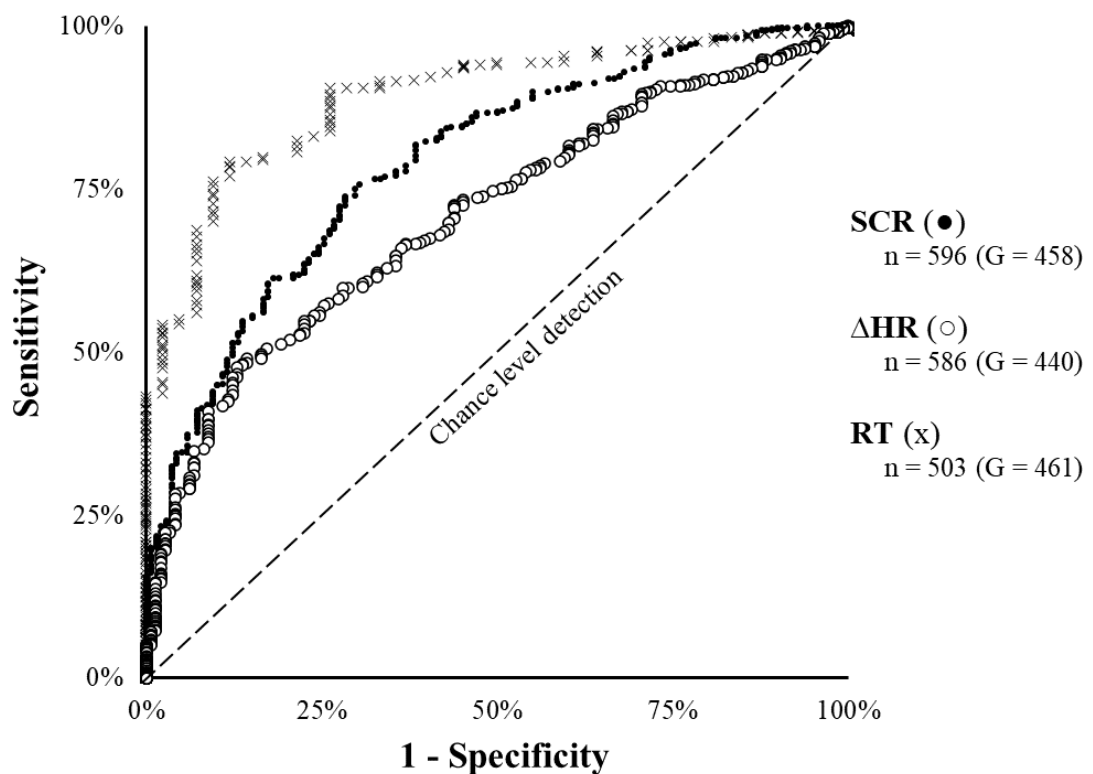


Figure 8.6. Signal detection curve (ROC) showing the detection sensitivity and specificity between guilty and simulated innocent participants for SCR,  $\Delta$ HR and RTs



## CIT Effect Sizes

Table 8.4. Mean Crime-Control Difference, Cohen's *d* and AUC

| Experiment                       |                                     |         |                |                  | SCR |                                       |                                       | ΔHR              |                                       |                                       | RT               |                                       |                                       |                  |
|----------------------------------|-------------------------------------|---------|----------------|------------------|-----|---------------------------------------|---------------------------------------|------------------|---------------------------------------|---------------------------------------|------------------|---------------------------------------|---------------------------------------|------------------|
| CH                               | Study                               | Exp No. | <sup>1</sup> C | <sup>2</sup> Sim | N   | <sup>3</sup> Mean z-scored crime item | <sup>4</sup> Guilty-Innocent <i>d</i> | <sup>5</sup> AUC | <sup>3</sup> Mean z-scored crime item | <sup>4</sup> Guilty-Innocent <i>d</i> | <sup>5</sup> AUC | <sup>6</sup> Mean z-scored CIT effect | <sup>4</sup> Guilty-Innocent <i>d</i> | <sup>5</sup> AUC |
| 2                                | Scenes                              | 1       | -              | Y                | 36  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.318                                 | 1.925                                 | 0.919            |
|                                  |                                     | 2       | -              | Y                | 44  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.212                                 | 1.009                                 | 0.746            |
|                                  |                                     | 3       | PC             | Y                | 50  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.286                                 | 1.506                                 | 0.875            |
|                                  |                                     |         | C              | Y                | 48  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.262                                 | 1.141                                 | 0.810            |
| 3                                | Shared Knowledge and Paired Testing | 1       | -              | Y                | 32  | 0.272                                 | 1.116                                 | 0.794            | 0.285                                 | 0.870                                 | 0.719            | -                                     | -                                     | -                |
|                                  |                                     | 2       | S              | Y                | 32  | 0.452                                 | 1.095                                 | 0.764            | 0.334                                 | 1.369                                 | 0.839            | -                                     | -                                     | -                |
|                                  |                                     |         | T              | Y                | 32  | 0.691                                 | 1.927                                 | 0.910            | 0.210                                 | 0.578                                 | 0.623            | -                                     | -                                     | -                |
|                                  |                                     |         | 3              | S                | Y   | 40                                    | 0.365                                 | 0.734            | 0.687                                 | 0.233                                 | 0.603            | 0.682                                 | -                                     | -                |
|                                  |                                     | T       |                | Y                | 44  | 0.489                                 | 1.106                                 | 0.768            | 0.293                                 | 1.214                                 | 0.810            | -                                     | -                                     | -                |
|                                  |                                     | 4       | T              | Y                | 30  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.212                                 | 0.824                                 | 0.824            |
|                                  |                                     | 5       | -              | Y                | 40  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.358                                 | 1.765                                 | 0.935            |
|                                  |                                     | 6       | S              | Y                | 32  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.203                                 | 1.250                                 | 0.812            |
|                                  |                                     |         | T              | Y                | 32  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.154                                 | 0.847                                 | 0.729            |
| 4                                | Investigator Influence              | 1       | -              | N                | 72  | 0.518                                 | 2.866                                 | 0.978            | 0.314                                 | 1.247                                 | 0.839            | -                                     | -                                     | -                |
|                                  |                                     | 2       | PC             | N                | 40  | 0.391                                 | 0.801                                 | 0.695            | 0.250                                 | 0.664                                 | 0.678            | -                                     | -                                     | -                |
|                                  |                                     |         | INV            | N                | 40  | 0.640                                 | 1.864                                 | 0.887            | 0.326                                 | 0.624                                 | 0.646            | -                                     | -                                     | -                |
| 5                                | Virtual Reality                     | 1       | PC             | N                | 64  | 0.200                                 | 0.785                                 | 0.708            | 0.179                                 | 0.598                                 | 0.670            | -                                     | -                                     | -                |
|                                  |                                     |         | VR             | N                | 64  | 0.412                                 | 1.758                                 | 0.902            | 0.164                                 | 0.488                                 | 0.640            | -                                     | -                                     | -                |
| 6                                | Fading Memories                     | 1       | 1W             | Y                | 22  | 0.367                                 | 1.107                                 | 0.798            | -                                     | -                                     | -                | -                                     | -                                     | -                |
|                                  |                                     |         | 2M             | Y                | 22  | 0.170                                 | 0.705                                 | 0.698            | -                                     | -                                     | -                | -                                     | -                                     | -                |
|                                  |                                     | P       | -              | Y                | 43  | 0.158                                 | 0.559                                 | 0.639            | 0.139                                 | 0.553                                 | 0.654            | -                                     | -                                     | -                |
|                                  |                                     | 2       | -              | Y                | 40  | 0.505                                 | 1.700                                 | 0.873            | 0.175                                 | 0.308                                 | 0.608            | -                                     | -                                     | -                |
| 7                                | Verticality                         | 1       | -              | Y                | 77  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.149                                 | 0.693                                 | 0.692            |
|                                  |                                     | 2       | -              | Y                | 28  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.286                                 | 1.446                                 | 0.852            |
|                                  |                                     | 3       | -              | N                | 87  | -                                     | -                                     | -                | -                                     | -                                     | -                | 0.187                                 | 1.457                                 | 0.853            |
| 8                                | Pilot Studies                       | 1       | -              | Y                | 40  | 0.432                                 | 0.892                                 | 0.722            | 0.295                                 | 0.806                                 | 0.714            | -                                     | -                                     | -                |
|                                  |                                     | 2       | -              | N                | 21  | 0.303                                 | 1.188                                 | 0.825            | 0.148                                 | 0.904                                 | 0.720            | -                                     | -                                     | -                |
| Mean                             |                                     |         |                |                  | -   | 0.398                                 | 1.263                                 | 0.791            | 0.239                                 | 0.773                                 | 0.703            | 0.239                                 | 1.260                                 | 0.822            |
| Combine (Innocents) <sup>7</sup> |                                     |         |                |                  | N   | 0.410                                 | 1.343                                 | 0.826            | 0.236                                 | 0.669                                 | 0.681            | 0.187                                 | 1.457                                 | 0.853            |
| Combine (Simulated) <sup>8</sup> |                                     |         |                |                  | Y   | 0.399                                 | 1.053                                 | 0.764            | 0.242                                 | 0.704                                 | 0.686            | 0.233                                 | 1.135                                 | 0.801            |
| Weighted d* <sup>9</sup>         |                                     |         |                |                  |     |                                       | 1.23                                  |                  |                                       | 0.757                                 |                  |                                       | 1.24                                  |                  |

<sup>1</sup> Between subject condition; T = Tested together, S = Tested Separately, PC = Computer Condition, INV = Tested by Investigator, VR = Virtual Reality, 1W = Testing within one week, 2M = Tested after 2 months

<sup>2</sup> S = Simulated Innocents, I = real tested Innocent participants

<sup>3</sup> Normalized Mean crime response for guilty participants

<sup>4</sup> Cohen's *d* for Guilty-Innocent differences

<sup>5</sup> Area Under the Signal Detection Curve

<sup>6</sup> Mean crime minus control for guilty participants in milliseconds

<sup>7</sup> Combine analysis for only experiments where innocent participants were tested

<sup>8</sup> Combine analysis using simulated innocents for all data including those with innocent participants tested

<sup>9</sup> Weighted *d*\* =  $d / (1 + (.75/N - 3))$ , where N = sample size. Recommended and reported by [Meijer et al., 2014](#)

### Innocent vs. Simulated

Mean normalized SCR,  $\Delta$ HR and RT CIT effects were analyzed using a one-way ANOVA for Suspect type (Guilty vs. Innocent vs. Simulated) (Figure 8.7).

Guilty participants had larger SCRs,  $t(594) = 10.97, p < .001, d = 1.07, MD = .396$ ;  $\Delta$ HR,  $t(585) = 6.71, p < .001, d = .641, MD = .225$ , and RT,  $t(501) = 8.70, p < .001, d = 1.40, MD = .277$ , CIT effects compared to tested innocents. There was no difference between simulated and tested innocent participants CIT effects for SCR,  $t(457) = .915, p = .360, d = .093, MD = .032$ , and HR,  $t(428) = 1.59, p = .112, d = .162, MD = .058$ . However, tested (non-simulated) innocent participants showed a smaller RT-CIT effect than the simulated group,  $t(501) = 10.3, p < .001, d = 1.66, MD = .216$  – note however that only 43 were tested (not simulated) innocent participants in this thesis.

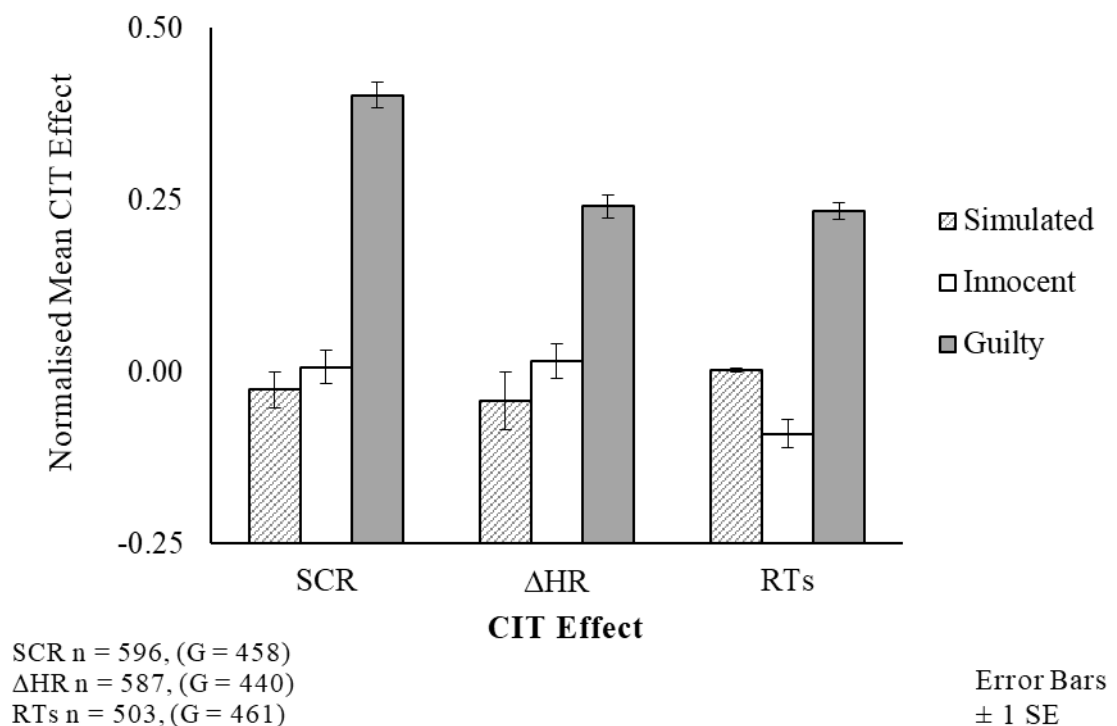


Figure 8.7. CIT effect for SCR,  $\Delta$ HR and RTs for Guilty, Innocent and Simulated

*Innocent suspects*

### Time-series Plots

Grand mean time-series plots for normalized SCR and heart rate responses to crime and control items are provided separated by whether the suspect was knowledgeable i.e. guilty, or unknowledgeable i.e. innocent and crucially whether a verbal “no” response was required or not ([Figures 8.8-8.11](#)). These plots were created by averaging the normalized EDA and heart rate response at each second, in one second intervals, from the start of the trial to 15 seconds after (which was typical the end). This was done for all CIT crime and control (minus buffer) trials across both guilty and innocent participants. Similarly, [Figures 8.12-8.13](#) are provided to show a typical CIT question/block with all EDA and heart rate responses averaged per second for each trial. Note that each control item is the mean second-by-second response for all control items in that specific positions i.e. 1<sup>st</sup> (buffer), 2<sup>nd</sup> – 5<sup>th</sup> whereas crime responses are averaged across all crime trials regardless of position in the CIT question. Finally, the distribution of all guilty participants normalized SCR, heart rate and RT responses to both crime and control items are plotted in [Figure 8.14](#) to show the distribution difference.

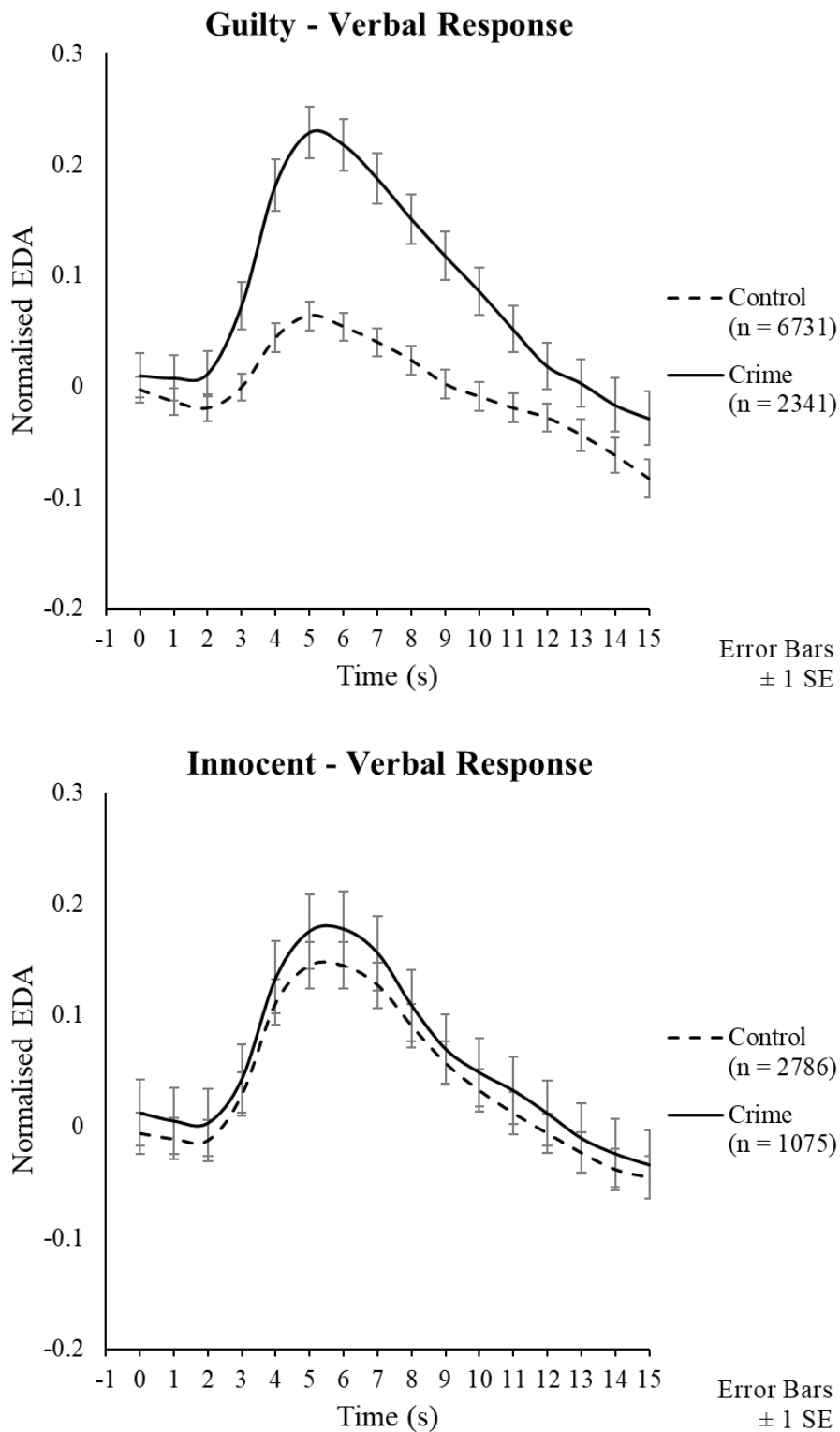
**Grand Mean SCR Response**

Figure 8.8. Grand mean normalised EDA time-series averaged over all trials with a verbal “no” response split by suspect. Stimuli onset at 0s, stimuli offset ranging between 4-6 seconds and end of CIT trial at 15s.

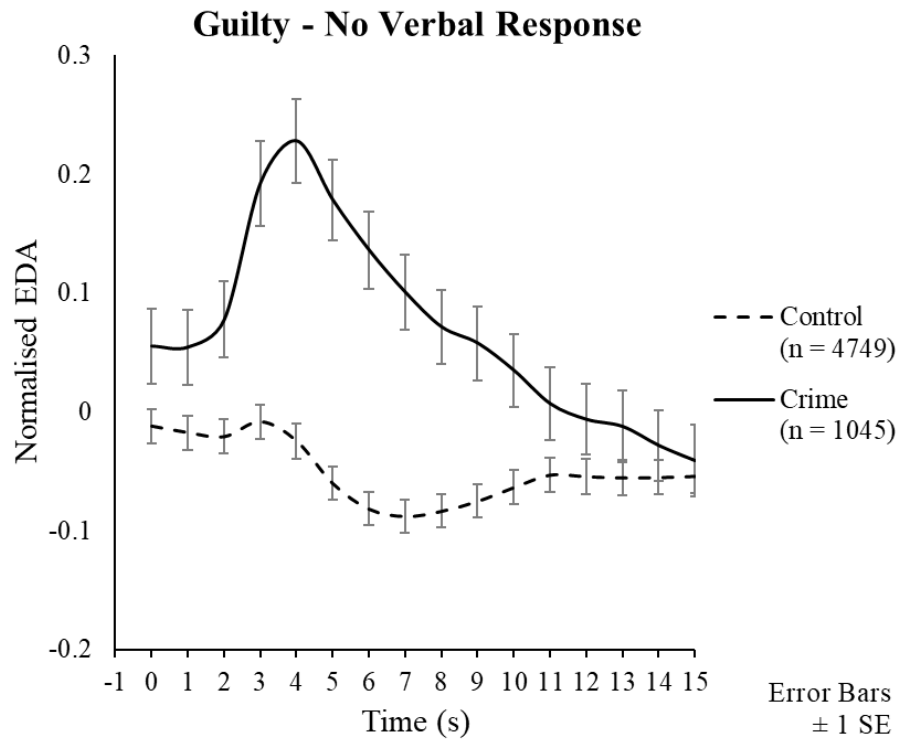


Figure 8.9. Grand mean normalised EDA time-series averaged over all trials with a no verbal i.e. silent response split by suspect. Stimuli onset at 0s, stimuli offset ranging between 4-6 seconds and end of CIT trial at 15s.

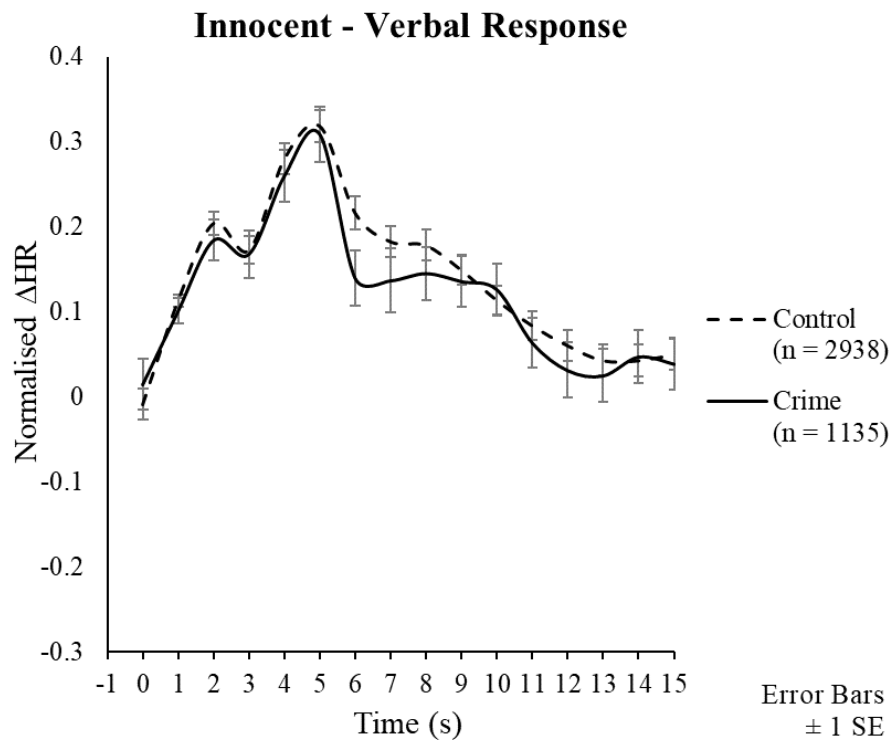
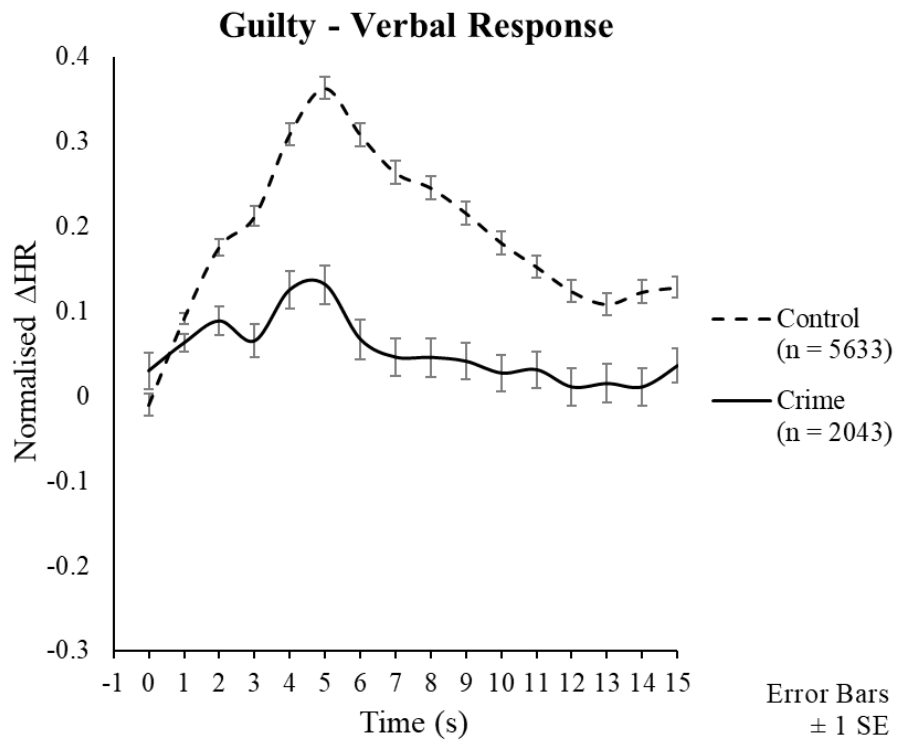
**Grand Mean  $\Delta$ HR Response**

Figure 8.10. Grand mean normalised heart rate change time-series averaged over all trials with a verbal “no” response split by suspect. Stimuli onset at 0s, stimuli offset ranging between 4-6 seconds and end of CIT trial at 15s.

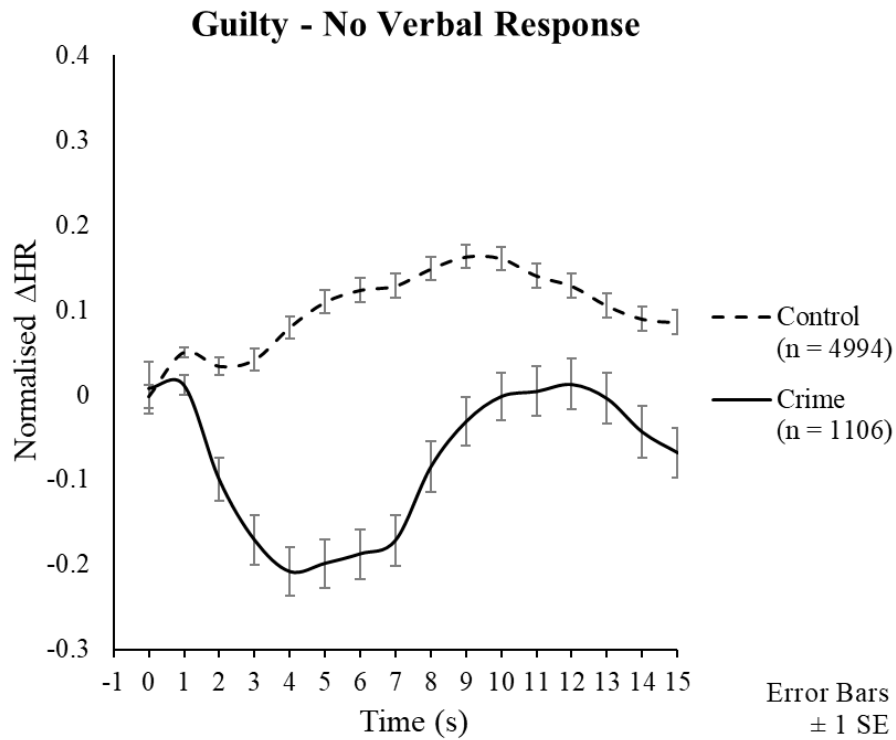
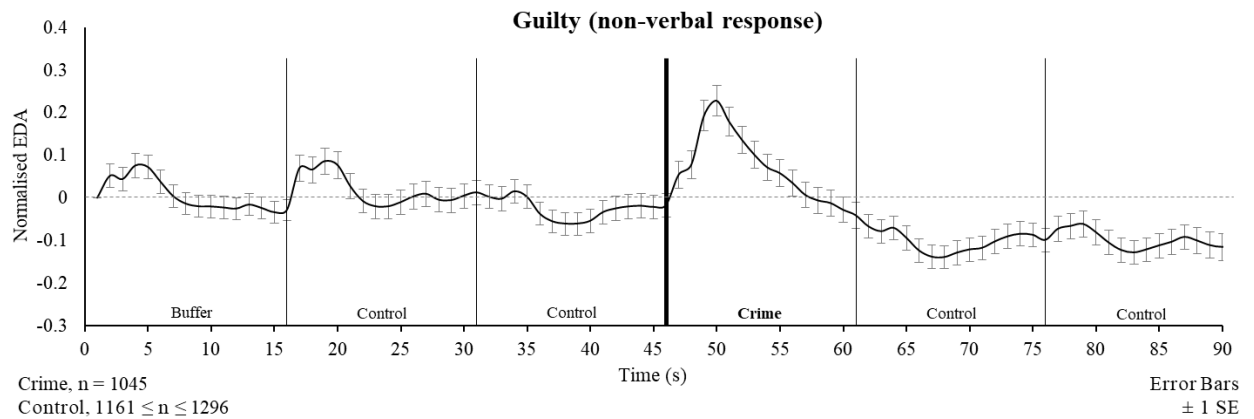
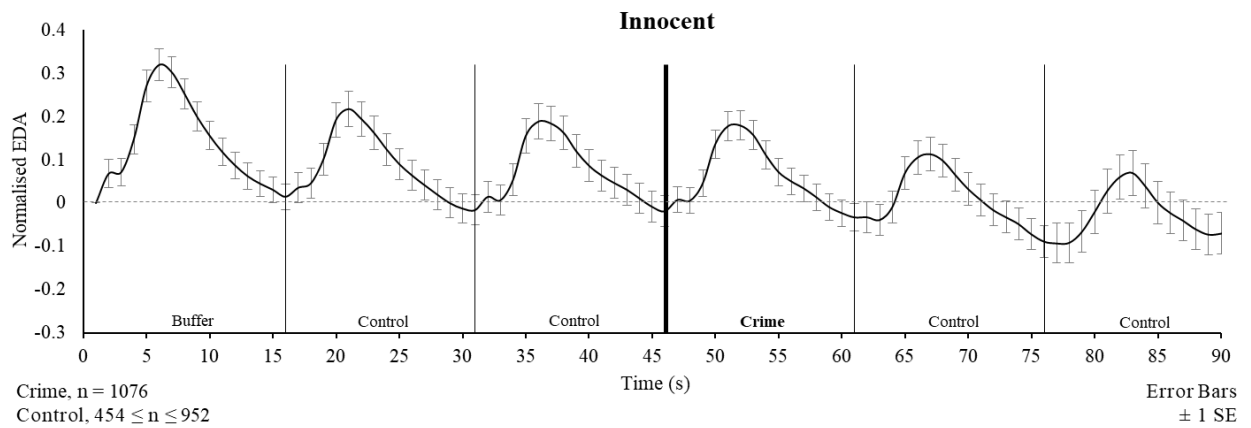
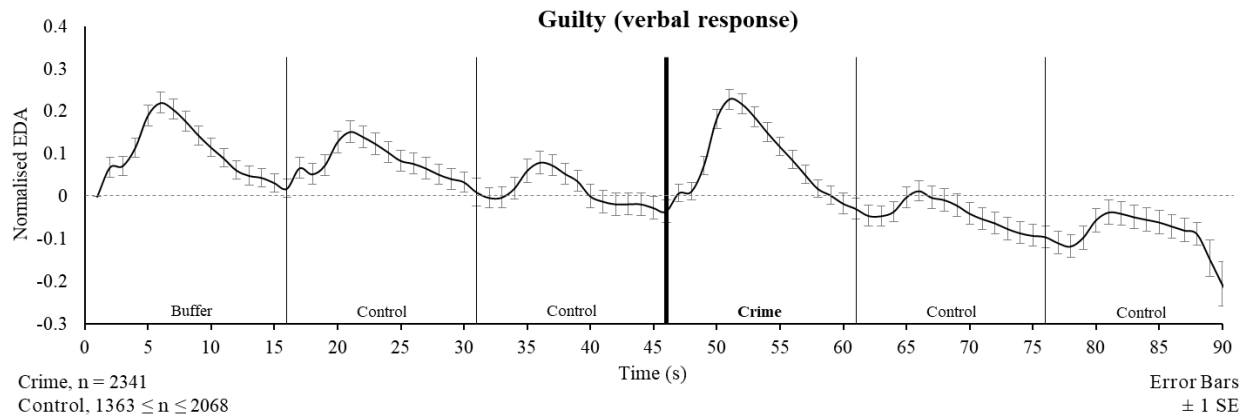
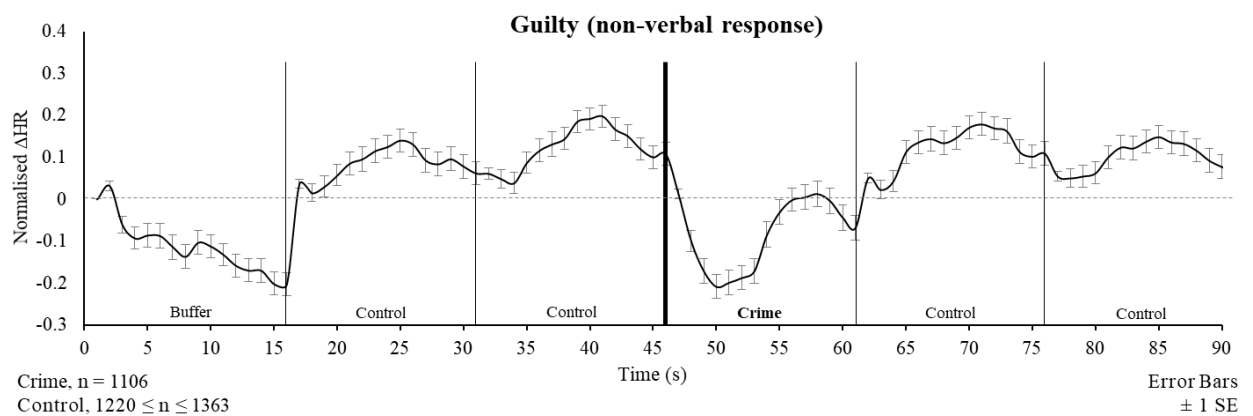
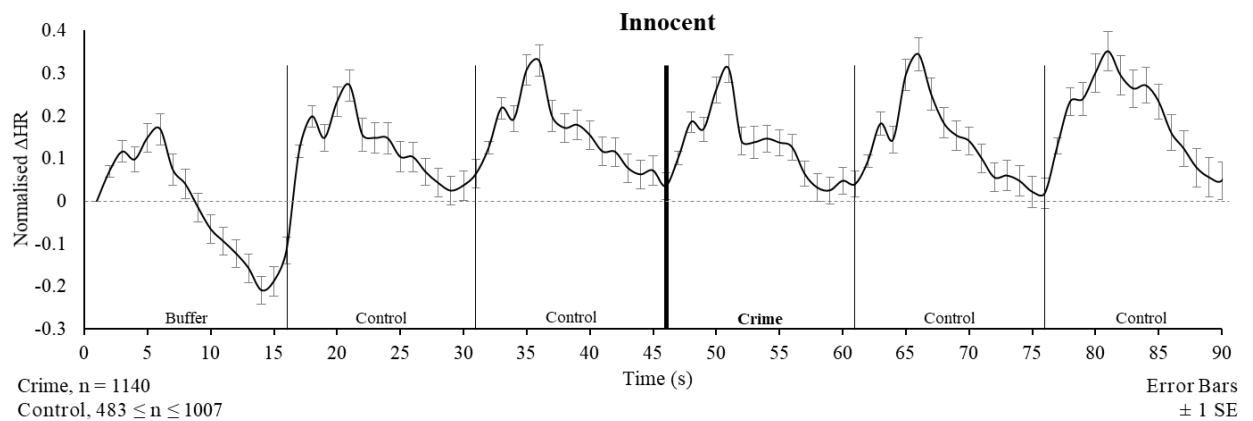
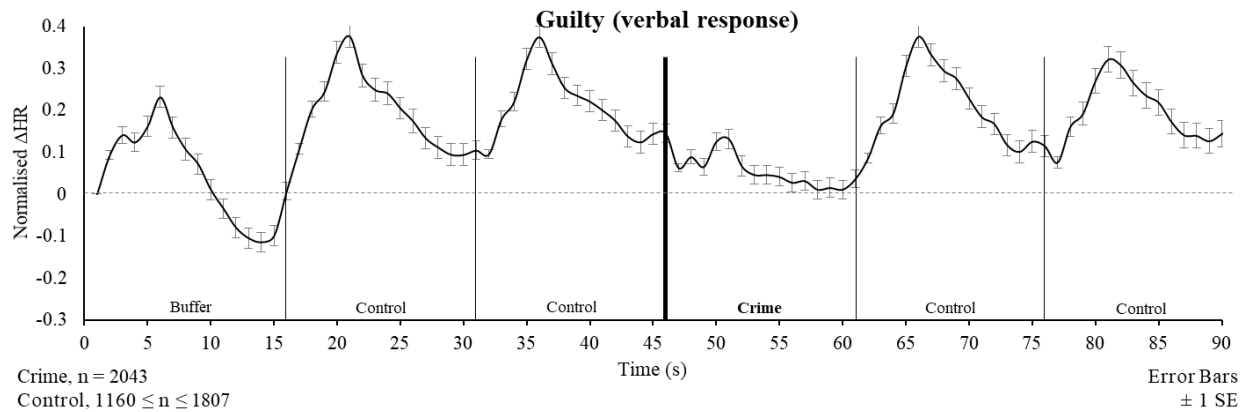


Figure 8.11. Grand mean normalised heart rate time-series averaged over all trials with a no verbal i.e. silent response split by suspect. Stimuli onset at 0s, stimuli offset ranging between 4-6 seconds and end of CIT trial at 15s.

**Grand Mean SCR CIT**

*Figure 8.12. Grand mean normalised EDA time-series averaged over each trial within a CIT and split by suspect and whether a verbal “no” response was given or not. Stimuli onset at 0s, stimuli offset ranging between 4-6 seconds and end of CIT trial at 15s.*



**Grand Mean  $\Delta$ HR CIT**

*Figure 8.13. Grand mean normalised heart rate change time-series averaged over each trial within a CIT and split by suspect and whether a verbal “no” response was given or not. Stimuli onset at 0s, stimuli offset ranging between 4-6 seconds and end of CIT trial at 15s.*

## Response Distributions

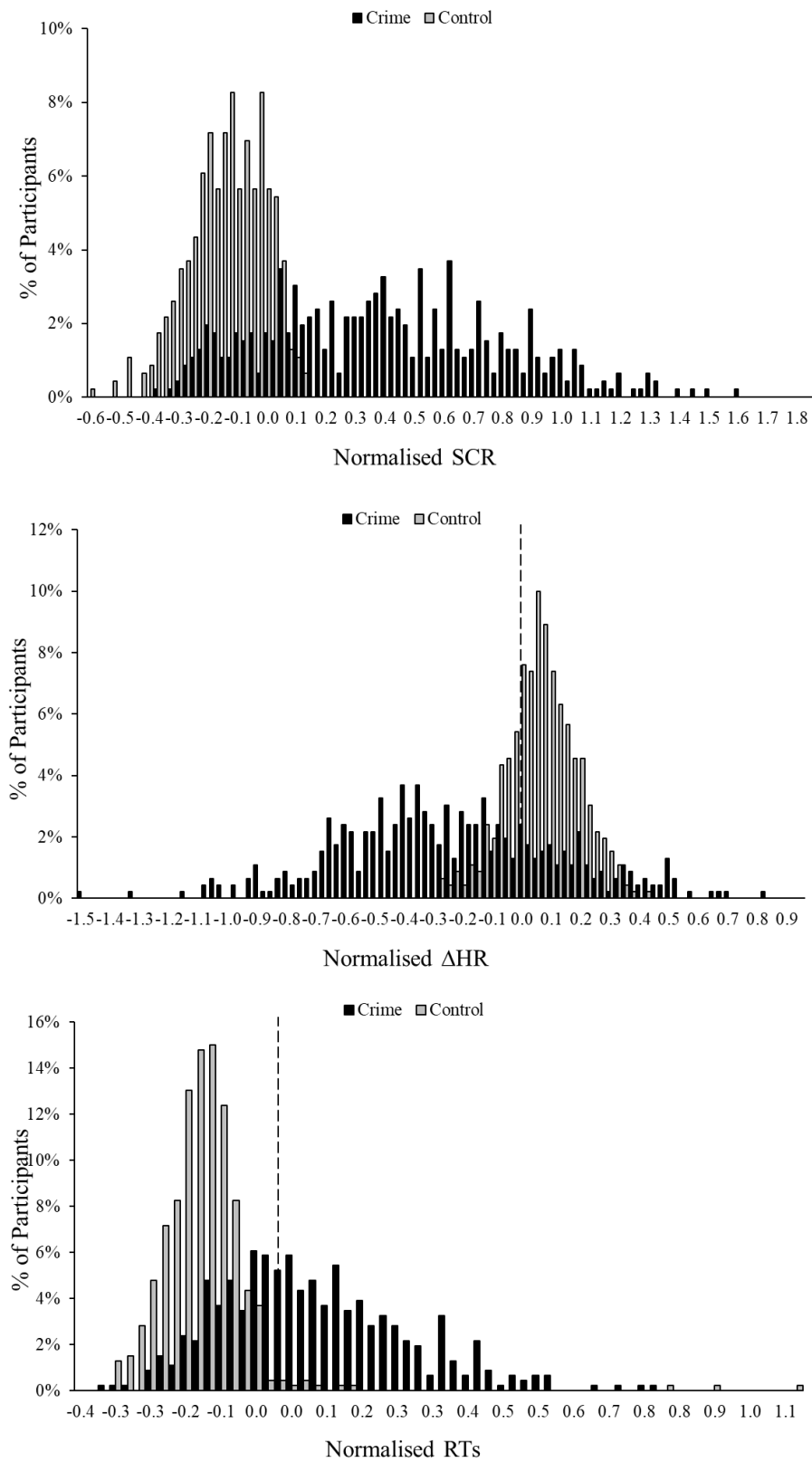


Figure 8.14. Distribution of mean normalised SCR,  $\Delta HR$  and RTs for crime and controls

## Discussion

A mega-analysis of all data reported in this thesis ( $n = 1150$ ) was conducted. The main findings were that self-reported (Likert scale 1<sub>low</sub> – 6<sub>high</sub>) ‘motivation to beat the CIT’ and self-reported ‘stress during the CIT’ did not appear to impact the CIT effect whereas ‘perceived CIT performance’ did, although not in a linear fashion. Self-reported countermeasure use and the type of countermeasure used had no effect on CIT detection. Overall, the results of the picture-based CITs showed that the effect size and diagnosticity were largest for the RT-CIT ( $d = 1.61$ ,  $AUC = .891$ ) with SCR being larger ( $d = 1.15$ ,  $AUC = .792$ ) than the  $\Delta HR$  measure ( $d = .765$ ,  $AUC = .708$ ) in the physiological CIT and this was not affected by the type of picture stimulus used (objects, scenes or faces). Finally, innocent participants showed similar physiological CIT effects to simulated innocent data although this finding is less clear for the RT-CIT.

The findings suggest that participants’ self-reported motivation to avoid detection did not relate to their actual performance as measured by the CIT effect. Although this is similar to the findings in a recent deception detection meta-analysis (Hartwig & Bond Jr, 2014), CIT meta-analyses have found that increased motivation to avoid detection results in increased CIT effects when using SCR and  $\Delta HR$  (Ben-Shakhar & Elaad, 2003; Meijer et al., 2014). This difference may be due to the manner in which motivation was measured. In previous work motivation is typically manipulated by promise of a reward or punishment if the participants avoided detection. In this thesis however, self-reported motivation was measured using a 6-point Likert scale on a paper questionnaire given after the CIT. Arguably this approach accounted for participants’ individual levels of motivation independent of extrinsic incentives and therefore provided a more valid estimate of the effects of

motivation on CIT detection. This interpretation, however, is premature for a number of reasons. Firstly, the spread of motivation responses was limited with 74% of responses being at the higher end of the motivation scale (5 and 6). This is likely due to the fact that in most experiments in this thesis, participants were incentivized with receiving their 'lie detection score' and a possible cash prize. Although anecdotal, the author noted early on in their experimental plan that participants were particularly motivated by the offer to receive their score, particularly as they knew that their score would be ranked against the other participants. The question of whether motivation modulates the CIT is important as it speaks to the validity of the CIT when it's applied in fields where real suspects are likely to be more motivated to conceal information about a crime they have committed.

For self-reported stress, few previous studies have investigated the effects of stress on the CIT but those that have, found no effect ([Ben-Shakhar & Nahari, 2018](#)). In those studies, stress was manipulated through the use of punishment for detection ([Bradley & Janisse, 1981](#); [Kugelmass & Liebllich, 1966](#)) whereas in the current study self-reported stress during the CIT was measured. For SCR, the results revealed no overall effect of stress suggesting that self-reported stress during the CIT did not relate to their responses to crime items. Guilty participants did however report feeling more stressed than innocent participants during the CIT which is unsurprising given the perceived stakes were considered higher. The effect of stress on the CIT is often considered to relate closely to motivation ([Meijer et al., 2014](#)), however, in this study no correlation was found between these factors. Similar to the findings for motivation reported above, the stress findings do not mesh with those in the literature. Again, this could be because the self-reported measures in the current meta-analysis provided a more valid assessment of the individual stress felt by each

participant taking into account their individual differences – this appears to be supported by the evenly spread stress ratings. Clearly further research is required as, if increased stress does result in increased detection then this suggests that lab studies, where stress is relatively low compared to field CITs, might be underestimating CIT detection.

Participants were asked how well they felt they did at appearing innocent in the CIT i.e. their self-evaluated performance at avoiding detection. The single previous experiment investigating the effects of self-assessed lie performance on the CIT found that the SCR CIT effect was larger for those rating their lie detection abilities as high (Elaad & Sommerfield, 2016). It was suggested that this may be due to different levels of motivation to avoid detection as participants that believed they were good liars may have felt more motivated to prove so in the CIT - however this had not been explored (Elaad, 2018). In the current study, self-reported perceived performance was positively correlated ( $r = .151$ ) with motivation i.e. participants that believed they performed better were more motivation to avoid detection.

Additionally, self-reported perceived performance was negatively correlated ( $r = -.107$ ) with stress i.e. stressed participants believed they had performed worse in the CIT. Similar findings have been found more broadly where participants' self-evaluations are positively related to self-reported motivation and task performance (Erez & Judge, 2001; Humphreys & Revelle, 1984; Schunk, 1995). Furthermore, this mega-analysis revealed a main effect of perceived performance on SCR CIT performance. The SCR results suggest that participants who felt they had performed either poorly or very well on the CIT actually did not. However, this interpretation requires caution as corrected pairwise comparisons revealed no significant effects between each level; this was likely due to the very high significance threshold

required when pairwise comparisons are computed for 6 levels. Finally, as expected, guilty participants self-evaluated their CIT performance as worse than innocent participants.

Countermeasures have been found to be effective at reducing CIT detection, namely for SCR ([Ben-Shakhar & Nahari, 2018](#)). The few studies that have investigated the effects of countermeasures in the RT-CIT (including in Experiment 3, Chapter 3 of this thesis) have found that they do not significantly impact RT-CIT detection ([Suchotzki et al., 2017](#)). Unsurprisingly in this thesis, more guilty participants attempted countermeasures than innocent participants and with increased motivation revealed for guilty participants who attempted countermeasures. Interestingly, self-reported countermeasure use did not impact any CIT measure in the current meta-analysis and there was no difference between the types of countermeasures attempted. For  $\Delta$ HR and RTs this finding reflects those in the literature. However, the finding that SCR was not influenced by countermeasure use or type in the current work does not mesh with previous meta-analyses. A possible reason for this is that in previous CIT studies countermeasure instructions are provided to participants whereas in this thesis, with the exception of data collected in Experiment 3, Chapter 2, participants were simply asked to report any countermeasures, if any, that they chose to use. Clearly, most participants' countermeasure choice e.g. “remaining calm”, was inadequate for reducing CIT detection. Interestingly, controlling breathing was the most commonly reported countermeasure attempt even when respiration was not being measured. Although no effect of countermeasures was found, the choices of what type of countermeasure participants felt would assist them in fooling the CIT is useful information for future work in this area. Research into the effectiveness of countermeasures is important

because in field CITs, suspects are likely to attempt countermeasures to beat the CIT. The findings suggest, when suspects choose their own countermeasure, similar to what would be expected in the field, they do not choose strategies that adequately reduce the CIT effect.

Few CIT experiments have used picture stimuli, opting for text and verbal modalities instead ([Ambach et al., 2010](#)). Research on memory retrieval typically finds that memory is greater for pictures than for text ([Hockley, 2008](#)), however, previous CIT studies have not found a picture superiority effect in the CIT ([Ambach et al., 2010](#)). Picture stimuli were used in all CITs in this thesis. For picture stimuli, mean weighted CIT effect sizes<sup>1</sup> for SCRs ( $d^* = 1.23$ ) and  $\Delta\text{HR}$  ( $d^* = .757$ ) were lower than those reported in a previous meta-analysis where weighted effects sizes for SCR and  $\Delta\text{HR}$  are  $d^* = 1.55$  [ $1.44 - 1.66$ ,  $\text{CI}_{95\%}$ ] and  $d^* = 1.11$  [ $1.00 - 1.22$ ,  $\text{CI}_{95\%}$ ] ([Meijer et al., 2014](#)). The RT-CIT effect size ( $d^* = 1.24$ ) for picture stimuli however was similar to that reported previously  $d = 1.30$  [ $1.06 - 1.54$ ,  $\text{CI}_{95\%}$ ]

([Suchotzki et al., 2017](#)). Several reasons may account for the reduced effect sizes for SCR and  $\Delta\text{HR}$  reported in this thesis. First, some factors tested in this thesis resulted in reduced overall CIT effects including: i) fading stimuli on the screen (Chapter 6), testing participants over two month after the mock crime (Chapter 6), and having participants tested in pairs which negatively interacted with shared knowledge encoded (Chapter 3); ii) using only simulated innocents in computing  $d^*$  above which has been shown to be a more conservative estimate of effect size ([Meijer et al., 2014](#)); and; iii) inclusion of less salient or peripheral CIT stimuli to

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<sup>1</sup> Weighted  $d^* = d / (1 + (.75/N - 3))$ , where  $N$  = sample size is recommended and reported by [Meijer et al., 2014](#)

allow for larger numbers of questions required for within subject testing of various factors (e.g. eight plus stimuli in Chapters 3-4 and 6) – peripheral stimuli typically results in poor CIT effects (Ben-Shakhar & Nahari, 2018). Alternatively, the reduced effect sizes may simply be due to the use of picture stimuli - further work is needed to validate this. Finally, the type of picture stimuli did not impact the SCR and  $\Delta$ HR CIT effects, indicating that, just like object stimuli used in the literature, faces and scenes are also suitable as CIT stimuli (Ambach et al., 2010). This finding increases the possible number of crime details that could be included in a CIT which should increase overall detection (Meijer et al., 2014).

The assumption when designing a CIT is that all stimuli (crime and control items) are equally plausible to an innocent suspect. This property therefore permits the simulation of innocent participants in the absence of having tested an unknowledgeable group of participants (Meijer et al., 2007). However, a previous meta-analysis revealed that studies using an innocent group found higher detection rates ( $d = 1.64$ ) compared to those that simulated innocent participants ( $d = 1.39$ ) (Meijer et al., 2014). The work did not reveal a significant difference for SCR and  $\Delta$ HR as CIT effects were similar between simulated and tested innocent participants. However, for the RT-CIT, tested innocent participants showed smaller CIT effects than the simulated group. However, this finding should be interpreted with some caution because only the RT-CIT innocent participants ( $n = 42$ ) underwent a modified location-based RT-CIT, which was shown to interact with the CIT effect itself (Experiment 3, Chapter 7).

Throughout this thesis the CIT effect has either been determined by the SCR peak amplitude or the mean heart rate change across the trial. As a result, the temporal information of these physiological responses is ignored. To explore this



temporal aspect, grand mean time-series plots for normalized SCR and heart rate responses to crime and control items are provided separated by whether the suspect was knowledgeable i.e. guilty, or unknowledgeable i.e. innocent and whether a verbal “no” response was required or not ([Figures 8.8-8.11](#)). The results from [Figures 8.8-8.11](#) show that SCR and heart rate responses for crime and control items only differs for guilty participants knowledgeable about the crime – innocent participants show the same response to both types of items. Furthermore, compared to the silent response condition i.e. without a “no” response, the heart rate pattern for participants verbally responding with “no” differs due to an initial acceleration and, in this analysis a reduced deceleration - this difference has been found previously ([Verschuere et al., 2009](#); [Verschuere, Crombez, DeClercq & Koster, 2004](#)). Note however that silent responses were only required in the paired CIT study (Chapter 3) and hence this difference may be simply due to the factors (i.e. group testing and knowledge) manipulated in that study. Although this appears unlikely given that the shape of the SCR and heart rate change are typical compared to those in the literature (see [Ambach et al., 2008](#); [Peth, Suchotzki & Gamer, 2016](#); [Verschuere et al., 2009](#); [Ambach et al., 2012](#); [Ambach et al., 2011](#); [Suchotzki & Gamer, 2019](#)). Relatedly, [Figures 8.12-8.13](#) show a typical CIT question/block with all EDA and heart rate responses averaged per second for each trial. In both the SCR and heart rate CIT plots the response to the buffer is similar to the crime item (for guilty participants) due to the initially orienting to the question block. This illustrates the need to ignore the buffer, which must always be a control item, in any analysis of the participants CIT response.

Finally, the distribution of all guilty participants normalized SCR, heart rate and RT responses to both crime and control items are provided ([Figure 8.14](#)) and

show that the spread of responses to crime items is larger than that of control responses. Interestingly, [Figure 8.14](#) visually conveys the issue of determining participants concealed knowledge to individual crime items relative to control items and therefore the importance of average responses to either multiple or repeated CIT questions..

As part of this thesis, over 650 participants underwent a physiology CIT (SCR and often  $\Delta$ HR) and over 500 underwent a RT-CIT. Comparing these sample sizes against those in recent meta-analyses, the data from this thesis constitutes 17% of SCR data collected ([Meijer et al., 2014](#)) and 47% of data collected in an RT-CIT ([Suchotzki et al., 2017](#)). With this large data set it was possible to explore factors such as self-reported; motivation, stress, perceived performance and countermeasure attempted, as well as possible difference between picture stimuli type (objects, scenes and face) and to report the overall CIT effect sizes for picture-based CITs. The results reported here should be of interest to other researchers working with the CIT.

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## CHAPTER 9

### **What's CIT all mean?**

#### **Thesis summary and concluding remarks**

As demonstrated throughout this thesis, the Concealed Information Test (CIT) is a memory detection test that can establish whether a suspect recognizes crime related information that an innocent person would not know. Both physiological measures (skin conductance and heart rate) and reaction times (RT-CIT) can be used, with the latter seemingly producing greater detection rates (Chapter 8). The CIT effect (the difference between responses to the crime and control stimuli) was found to be robust with picture stimuli and resulted in excellent detection of concealed information. Previous studies have demonstrated that the CIT can be modulated by various factors including but not limited to: suspect motivation; countermeasure use; the number of crime items used; whether recognition is concealed or not; crime memory; whether crime information has leaked to innocent suspects; and finally the effect of simulating innocent suspects' data for establishing baseline detection rates (Meijer, Selle, Elber & Ben-Shakhar, 2014; Ben-Shakhar & Elaad, 2003; Suchotzki, Verschuere, Van Bockstaele, Ben-Shakhar & Crombez, 2017). The work in this thesis both expands upon existing modulating factors previously investigated (e.g. motivation, stress, self-assessed lying ability, countermeasures and delayed testing in Chapters 6 and 8), as well as exploring new factors not yet considered (e.g. scene stimuli, paired testing and group knowledge, investigator influence, virtual reality, verticality and gradually onset stimuli in Chapters 2 - 7). Given thorough discussions



are presented in each experimental chapter, this is a more general overview of the findings, their contribution to theory and practice and suggestions for further work. Additionally, some more speculative theories are discussed.

The more crime details available to test for a suspect's crime recognition, the more accurate the CIT will be at correctly detecting whether the suspect is guilty or innocent ([Meijer et al., 2014](#)). Although the CIT has widespread use in Japanese criminal cases ([Osugi, 2011](#)), one study found that it was difficult to identify an adequate number of crime details for use in the CIT ([Podlesny, 2003](#)). To increase the number of crime details available to the CIT examiner, scene images could be used. For example, scenes of a: burgled room; location used for acquiring illegal contraband; a target building for planned criminal activity; and areas with autobiographic connections. Using scene stimuli offers more potential crime details and also opens up new possible applications for the CIT, in situations where scene and location knowledge is important and can't be easily described in text. Unlike objects and words, scene images cannot always be labelled and therefore visual information is required to elicit recognition. A review of the CIT literature by the author indicated that scene stimuli had not been validated in the RT-CIT and had not been compared with object stimuli. One concern was that images of scenes tend to be more complex than objects and often contain many different features, depth related information and can also contain multiple objects and people. Further, the broader cognitive and neuroscience literature demonstrates that scene stimuli are processed differently to objects, and there was good reason to predict that RT-CIT detection may have decreased or been negated entirely ([Melcher, 2006](#); [Cleary & Reyes, 2009](#); [Munneke et al, 2013](#); [Oliva & Torralba, 2006](#)). In Chapter 2, scene stimuli were tested over three experiments, which revealed that, fortunately, scene stimuli elicit

comparable RT-CIT detection rates to images of objects and words. The findings from the study provide an important practical insight; scene stimuli are safe to use in the RT-CIT. Following this finding, scene stimuli were used throughout this thesis e.g. Experiment 3, Chapter 2 to test countermeasure susceptibility in the RT-CIT, Experiments 4-5, Chapter 3 to investigate paired testing and Experiments 1-2, Chapter 7 to explore the possible interaction between vertical stimulus positioning and the RT-CIT. One take home message from Chapter 2 then is that scene stimuli are acceptable in the CIT.

Group crime tends to be more high-profile and damaging than crimes committed by individuals (Zheng, Messner, Lu & Deng, 1997). To further complicate matters, not all members of a crime group have access to the same information about the planned or conducted crime. For example, consider a scenario where one crime member, we'll call them The Engineer, accessed a building from one side to deactivate an alarm system, whilst the other, The Safe-cracker, entered another part of the building to break into a safe and steal some money. The tools used and crime information encoded by the Engineer and Safe-cracker might not be shared by both of them, e.g. the Safe-cracker wouldn't necessarily know that the Engineer had used wire cutters to disable the power to the alarm. There would of course be information that both partners knew about the crime, such as how much money they stole and from where. This scenario is of course fictional; however, the principle applies to real criminal and indeed terrorist organizations where groups frequently operate. So, when members of a known crime group, or pair, are apprehended by the investigating authorities, should a CIT be administered to each member individually or together? One reason to test them together is that group CIT testing has been shown to be an effective way of extracting reliable information from

the group as a whole - particularly when all group members share the same information/knowledge about the planned or committed crime (e.g. [Elaad, 2016](#)).

Testing groups of people together may also increase detection of crime details compared to testing them alone. Referring back to the scenario above, intuitively, if the Engineer and Safecracker were sat next to each other in the CIT and they were then shown a crime item they both recognized e.g. the amount of stolen money, and they both knew that each other recognized the item, then it is reasonable to imagine that their physiological CIT response would be different compared to when an item appears that only one of them know, e.g. the wire cutters known to the Engineer.

This idea was tested over multiple experiments in Chapter 3. It was predicted that the CIT effect (crime minus control) would increase for the shared items compared to the items only known by one of the crime partners (termed exclusive knowledge in Chapter 3). Indeed, this is what was found for the SCR CIT effect, which was found to be higher when crime partners taking the CIT together shared knowledge of the crime stimuli presented.

Interestingly though, another effect emerged after pooling data from Experiments 2 and 3 in Chapter 3. When crime pairs viewed shared crime details in the absence of their partner i.e. when suspects were tested alone, the SCR CIT effect decreased. This was thought to be due to a mismatch between viewing crime items that were associated with a partner, but without having the partner present. Indeed this was in line with theories of Encoding Specificity ([Tulving & Thomson, 1973](#)), whereby groups encoding and retrieving the information alone benefit from both context-dependent learning (i.e. the lack of participants in their physical surroundings), as well as transfer-appropriate processing (i.e. similar cognitive processes used during encoding and retrieval) ([Barber, Rajaram & Aron, 2010](#)). This

group testing and shared knowledge interaction led to overall higher detection rates for concealed information when crime partners were tested together. The findings from this chapter, for the physiological CIT at least, provide interesting theoretical insights into the importance of paired testing. The initial results from this work warrant further exploration and validation, as, if generalizable, indicate that, at least for crime pairs, the CIT should be administered at the same time.

The second part of Chapter 3 considered the effect of group testing on the RT-CIT. As well as the reasons described above, the potential for group RT-CIT testing opened up additional applications. Using an RT-CIT, it would be relatively simple to conduct a preliminary assessment of who, in a large group of people, requires further investigation. For example, if someone was believed to be leaking information in an organization that dealt primary with confidential information, a rapid screen of all employees simultaneously could help triage an operation to find the culprit. This could be achieved, either in a room with many individual computers, or a room with one large screen presenting the stimuli and using individual low-latency wireless controllers. The question in this case is what is the effect of taking a group RT-CIT, rather than a physiological CIT? Do the people around you distract or focus the attention? What happens if the perpetrator is taking the RT-CIT alongside an accomplice? An initial attempt to explore these questions was made in Experiments 4-6 in Chapter 3. However, the results were less promising than those found for the physiological CIT. There appears to be either no benefit, or a cost of taking an RT-CIT with a crime partner. Further work should investigate whether these findings apply to larger group and if so whether the effect is linear.

When interrogating suspects, investigators will sometimes present the suspect with some physical (such as a murder weapon), or photographic material (such as a

crime scene), at key points in the interview. The investigators will then look to see how the suspect responds to this information, whether they recognize it or appear surprised, or whether the forensic evidence is enough to drive the suspect to confess. Procedurally, this is similar to the CIT where a suspect is presented with some pieces of crime information, alongside matched control information, to determine whether they recognise the incriminating crime details. Initially, this rationale prompted the idea of trying to incorporate a physiological CIT when attempting to establish whether a suspect recognizes the presented forensic evidence. However, there were some initial challenges to achieving this. Due to concerns about expectancy effects (Rosenthal, 2002; Meijer, Verschuere, & Ben-Shakhar, 2011, p. 300), the CIT had previously been tested almost solely using a computer. This was because research had shown that the presence of an investigator who was expecting a particular outcome, e.g., the outcome of the CIT, could influence the suspect to respond in a desired way that could increase false positive rates (Richard, Bond Jr, & Stokes-Zoota, 2003). This had been demonstrated a few times, when an investigator, knowledgeable about the target suspect, administered an eyewitness line up parade (Perlini & Silvaggio, 2007). Nevertheless, other findings specifically in deception detection indicated that an investigator may also increase detection for guilty suspects, due to the motivation impairment effect and difficulty of lying face-to-face (DePaulo et al., 2003; Hancock, Woodworth, & Goorha, 2010).

The author was surprised to find that no CIT studies had explicitly tested the impact of using an investigator to administer the CIT, compared to a computer administered equivalent. The rationale for this study then became more specific. Instead of just trying to simultaneously measure a suspect's recognition of forensic evidence presented by an investigator in an interview setting, the study aimed to

determine what the effects of using a human investigator were for both innocent and guilty suspects in the CIT. In Chapter 4, two experimental designs were used, a within subject (Experiment 1) followed by a between subject (Experiment 2) due to order interactions in the first experiment. In both experiments, there were two main conditions of interest, either the guilty or innocent suspects took a standard picture-based CIT on a computer monitor or were administered the CIT by a human investigator. The investigator, knowledgeable of the crime but unaware of the suspect's guilt, sat opposite the suspect and asked eight questions about the crime with each followed by the presentation of physical photographs one of which was the crime item. Every attempt was made to try and make the CIT feel like a structured interview whilst still adhering to the control timing required for fair comparisons to be made between physiological response to the crime and control image. This appeared successful and the CIT effect was not comprised. In fact, when participants were tested by the investigator, the SCR CIT effect increased for guilty suspects. Perhaps more interestingly, there was no effect on innocent suspects suggesting that no expectancy effects had occurred. Consequently, SCR CIT detection was higher for participants tested by the investigator.

Two conclusions were drawn from these initial findings. If this finding is robust, then use of an investigator, if done in a controlled manner, does not compromise the CIT as previously suspected. Additionally, the findings suggest that a CIT can be administered in a relatively naturalistic manner which could be incorporated into a structured forensic interview to detect deception. This approach may also be beneficial for the development of a covert CIT, where contactless (e.g. thermal imaging, pupil dilation) or unobtrusive physiological measures (e.g. hidden sensors in watches or chairs) are taken (Elaad & Ben-Shakhar, 2009; Lubow & Fein,

1996; Pollina et al., 2006). This line of research would be interesting to pursue, as a covert CIT would presumably reduce countermeasure use. Further work is required to assess the extent to which this is possible and within strict ethical guidelines.

For an optimal CIT to be administered, the guilty suspect must be able to easily recognize and differentiate the crime from the control items. Evidently this means that the stimuli used to represent the crime items must match the crime memory as closely as possible (Ben-Shakhar & Gati, 1987). Ideally, the suspect would be presented with the actual physical crime related object or scene. However, given the structure of the CIT, e.g. the presentation of multiple stimuli sequentially in a timed fashion, this is impractical. One solution is to digitally capture the crime objects and scenes and present them in a virtual reality (VR) where the objects and scenes can appear and disappear just like a standard 2D image CIT on a computer. Technologies for faithfully and efficiently recreating real-world crime objects and scenes is available and constantly developing (Puente, González-Jorge, Martínez-Sánchez & Arias, 2013). Based on memory theories such as *Context Reinstatement* (Godden & Baddeley, 1975), *Modality Congruence* (Lanen & Lamers, 2018) and *Feature Matching Theory* (Ben-Shakhar & Gati, 1987) described in Chapter 5, presenting photorealistic, 3D, 360° 1:1 scale CIT stimuli in VR should increase physiological recognition magnitude i.e. the SCR CIT effect. In Chapter 5, this is exactly what was found suggesting what could be termed a “*VR Superiority Effect*” named along the same lines as the classic *Picture Superiority Effect* (Hockley, 2008). The finding that SCR CIT detection was larger for participants tested in VR compared to using 2D images on a monitor was perhaps not too theoretically surprising. However, the initial finding that a VR-CIT is more diagnostic is promising for applied applications of the CIT. Forensic application of digital capture

technology is increasing, with some police forces in the UK now routinely laser scanning and creating 3D models of high-profile crime scenes. It is foreseeable that these developments could lead to such virtual crime and control stimuli being presented to suspects within the CIT.

The use of VR allowed the reinstatement of many features of the memory lost in 2D images such as depth, scale and 360° immersion. Typical comments from participants in the VR CIT condition was that when the crime related scenes were presented, it was 'like being back there'. Feature Matching Theory in the CIT indicates that physiological orienting is monotonically related to the similarity between the encoded and test stimuli ([Ben-Shakhar & Gati, 1987](#)). Therefore, in future research, the effect of introducing audio stimuli alongside the VR stimuli could further increase match between the encoded and retrieval stimuli. For example, if the crime was committed near a road, the background traffic noise could be introduced in the virtual recreation of the crime scene. More broadly, this study was the first to show that, when a memory is encoded in the real world, retrieval is stronger when the real-world environment is faithfully recreated in VR compared to just using a 2D photograph.

Related to Chapter 5, the impact of a weakened memory is a reduced SCR CIT effect. Unfortunately, memory strength deteriorates over time as the memory fades ([Murayama, Miyatsu, Buchli & Storm, 2014](#)). This is a problem in the CIT as, in real forensic situations, a suspect is rarely given a CIT immediately following the crime. Various studies have tested the impact of a delay after the crime and found that the CIT is relatively robust when crime details are explicitly remembered ([Ben-Shakhar & Nahari, 2018](#)). However, these studies have all used delays of less than a month (usually 1-2 weeks), despite over 50% of real CITs being administered two



months after the crime ([Hira, Sasaki, Matsuda, Furumitsu, & Furedy, 2002](#)).

Additionally, in most CIT studies, the participant is instructed to memorize the details in the crime, which clearly does not happen in the real world. In Chapter 6, participants took part in a mock crime without instruction to remember any details. Participants then took a CIT either within one week or after two months. The results revealed two important findings: i) the CIT effect size was still sizeable even after two or more months later, suggesting that overall CIT detection is relatively robust to the effects of time; but ii) the CIT effect after two months was smaller than the one-week group, even after excluding trials that the participants had forgotten. The latter findings indicated that the fading of memory over time decreases the CIT effect. Practically then, just as in Chapter 5, memory strength is related to the CIT effect and therefore, where possible, suspects should be administered a CIT soon after a crime.

The idea that memory which has faded over time results in weakened recognition was followed up in a speculative post hoc experiment (Experiment 2, Chapter 6). The idea was that recognizing an image after memory has faded over time is similar to trying to recognize an image that is blurred or faded like an old photograph as it is more difficult and takes longer to recognize ([Costen et al., 1994](#); [Collishaw & Hole, 2000](#); [Lewis & Edmonds, 2003](#); [Hole, George, Eaves, & Rasek, 2002](#); [Brockdorff & Lamberts, 2000](#)). To test this, image stimuli were either slowly faded on to a monitor to simulate a faded/weaker memory or presented abruptly in the standard fashion. Based on the findings from the previous experiment, i.e. a reduced SCR CIT effect when memory had faded due to a delayed CIT, it was predicted that the CIT effect would be smaller for gradually onsetting stimuli. An alternative hypothesis suggested a CIT detection benefit from avoiding abrupt onsetting stimuli. It was theorised that removal of the noisy orienting component that

related to the stimulus luminance, which is unrelated to the significance of the crime or control stimuli, would allow for a purer CIT orienting response, resulting in increased detection ([Turpin, Schaefer & Boucsein, 1999](#); [Turpin & Siddle, 1979](#); [Boucsein, 2012](#)). The first prediction was supported, and the CIT effect decreased when stimuli were faded gradually onto the screen. This is an interesting finding as it speculatively suggests that fading stimuli on the screen can be used as a method for simulating a faded memory, without the requirement for a long delay between encoding and testing. Clearly, much more work would need to be done to confirm this, but it is an interesting idea, nevertheless.

Metaphorical concepts such as good, powerful, positive and moral have been found to be preferred, processed faster and recalled easier when presented in a high vertical position compared to a low one; the opposite is true for the reverse concepts ([Cian, 2017](#); [Meier & Robinson, 2004](#); [Crawford et al., 2006](#); [Meier, Sellbom & Wygant, 2007](#)). This interesting finding has been termed Verticality and is simply the relative positioning of stimuli in the vertical dimension and its relationship to metaphorical concepts. Deception is usually considered a negative or immoral act and having to lie is for most a negative experience. Plausibly then there could be a verticality effect for deception, as stimuli requiring a lie response (e.g. crime items) might be processed faster with a low verticality, and slower with a high verticality. The opposite could also be true, where truthfully responding (e.g. to a control item) would be facilitated in a high vertical position relative to a low. If these predictions are true then they may result in a larger CIT effect if verticality interacts with the RT-CIT. This would occur as the mismatch between crime (negative/immoral) stimuli being presented on top (where positive/moral stimuli are preferred) would slow down processing for guilty participants, only and contribute to response inhibition. This

was tested in Chapter 7, which revealed the expected, yet still surprising, result that RTs were slower to crime items presented at the top of the screen compared to the bottom resulting in an increased RT-CIT effect. This is an unusual finding and brings together two seemingly unrelated fields in psychology. Further work would be required to confirm and generalize these findings to more stimuli. However, if this verticality-CIT interaction holds then there are a few possible implications. First, RT-CIT detection could be increased by only considering items presented on top of the screen; but note that stimuli would also need to be presented on the bottom as well to generate the relative verticality effect. Second, it means that deception is considered incompatible with concepts that relate to higher verticality such as positive and good. Theoretically this finding could be used to explore how different populations, e.g. criminals, view deception. Given that the verticality-CIT interaction likely relies on the conceptual metaphor that deception is negative, it would be prudent to confirm that the effect is still present when the suspect truly believes that the deception is justified. This could be explored by either positively or negatively framing a mock 'crime' and then comparing participants' verticality effects.

A decision was made early in the author's experimental plan to give all participants a standardized post CIT questionnaire to record self-reported: motivation to avoid detection; stress felt during the CIT; perceived performance to avoid detection/appearing innocent; and countermeasure use and type e.g., "control my breathing". This meant that after all data collection had been completed, a mega-analysis of this self-reported data could be conducted. All of these factors have been previously shown to modulate the CIT ([Meijer et al., 2014](#); [Elaad & Sommerfield, 2016](#); [Bradley & Janisse, 1981](#); [Kugelmass & Liebllich, 1966](#)). However, in all cases, they were measured differently i.e. not using self-reports. Self-reports were chosen as

a measure of motivation, stress, perceived performance and countermeasure use, as they allow individual differences to be accounted for. For example, some participants are likely to be less motivated by an extrinsic factors, e.g., as financial rewards, however it is monetary incentives that are often used in the literature ([Meijer et al., 2014](#)). Similarly, some participants found the CIT more stressful than others, regardless of the condition manipulated e.g. use of an investigator to administer the CIT. Of course, using self-report measures meant that a large number of participants per point were needed for a meaningful analysis. Over 1100 participants were collected across all 20 experiments in this thesis with 450 given the post CIT self-report questionnaire. The results revealed that motivation to avoid CIT detection, stress and countermeasure use did not impact the CIT despite previous findings using non self-reported measures showing otherwise. Additionally, perceived CIT performance did affect the CIT in a non-linear fashion, which has also not been demonstrated previously. These results should be of interest to other researchers working with the CIT.

In sum, the work in this thesis indicates that the CIT is affected by: i) the use of a human investigator which was found to increase CIT detection; ii) presence of a crime partner which increases physiological CIT detection for when information is shared among pairs with negative effects for the RT-CIT; iii) presentation of the CIT in virtual reality which results in increased detection compared to on a computer; iv) the delay between crime and CIT and whether stimuli are faded, both of which reduce CIT detection; v) the stimuli's vertical position where the RT-CIT effect is larger for items presented incongruently on top (top is associated with good/positive) and; vi) self-reported stress felt during the CIT participants and self-reported performance at avoiding detection. Finally, the CIT was found to be robust to: i)

scene stimuli in the RT-CIT; ii) countermeasure use; iii) picture stimuli and; iv) self-reported motivation to avoid detection.

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## APPENDIX

### **Materials, Programs, Data, Unfinished Work and Corrections**

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## **APPENDIX 1**

### **EXPERIMENT MATERIALS**

## Setup

Department of Psychology: Experiment Set Up  
Partners in Crime - Shared Information and Paired Testing in the Concealed Information Test  
Researchers: Danni Norman, Abdullah Khan & Derrick Watson

### Concealed Information Test Lab Set up (Stimuli Lab C7)

#### Before Participant Arrives

1. Check consent forms and instructions ready
2. Check debrief form ready
3. Check memory and feedback sheet is ready
4. Check electrodes
5. Open stimuli videos ready on desktop
6. Check Speaker volumes
7. Full screen videos
8. Set displays to side-by-side 3D ("3D" -> right -> up)
9. Connect glasses and test 3D

#### Participant Arrives

\*ATTACH SENSORS

#### Participant Enters Testing Lab

1. Change screen back to 2D
2. Open team viewer and link to the other PC (type 1 -> IACSC8)
3. When investigator starts investigator condition press record on the investigator facing webcam
4. Wait until participant has finished both conditions and then stop biopac acquisition and webcam recording
5. Take participant back to stimuli lab

#### Participant Memory Check & Debrief

\*Go through memory check sheet

2. Give short verbal debrief and offer written debrief to take
3. Answer any questions

*Figure A.1. Setup for Partners in Crime similar for Experiments 1-3 (pg 1/2)*



### **Concealed Information Test Lab Set up (Testing Lab C8)**

#### **Before Participant Arrives**

1. Check Investigator instructions
2. Locate program to run
3. Move any data files from previous experiment to correct folder
4. Open Acqknowledge template
5. Go to Media set up and change File Out name to P Number
6. "Check for Hardware" button and select the biopac machine ID
7. Save Acqknowledge template as Participant Name and Experiment – Filename LM(Pnumber)
8. Tidy / untangle electrode cables

#### **Participant Arrives**

*\*Go through Investigator sheet*

#### **Participant Memory Check & Debrief**

1. Save the physiology data and webcam video!
2. Move these to appropriate folder and name



*Figure A.2. Setup for Partners in Crime similar for Experiments 1-3 (pg 2/2)*

### RT CIT Program Instructions

#### Note:

1. Leave all hidden files
2. Running program from memory stick not advised
3. Images are in "Experiment" folder
4. Output data is saved into "RT Data"
5. To prematurely stop the program, use [Alt] + [Ctrl] + [del] to escape

#### Setting Up:

1. See "Trial Config Files" folder
2. Set Display Config – Find "DisplayConfig" file and set resolution to resolution of screen. Set bit colour to 32.
3. Open tc1 and type in the 5 probe items being used (with enter between each one) – order doesn't matter.
4. File "RT Main Config" is where all the CIT parameters can be changed.
  - a. Default set at 5 CITs (therefore 5 probes) each containing 4 irrelevant and 1 target. Therefore 30 images make up one trial (taking around 1 minute to do)
  - b. Each one of these trials is repeated 3x (or 1x in practice round) to make 1 block of 90 images
  - c. Each test contains 5 blocks (1x for practice round) therefore totalling 450 images. This is therefore 15 repeats of the probe.
  - d. At the end of every Rep (i.e. 30 images) there is 6 second break before the next one.
  - e. At the end of a block there is a 30 second break
  - f. The image appears for 800ms (unless a response is given – only applies to single CIT test). Time between each image is random between 500, 800 & 1000ms
  - g. The 'question' for each image is "Do you recognise this scene?"
    - i. Participant 1, responses are [Left] for "yes" and [Right] for "No"
    - ii. Participant 2, responses are [Z] for "yes" and [C] for "No"
    - iii. If no response given within 800ms then feedback "Too Slow" is shown on the respect side of the screen (right side of participant 1, left side for participant 2)
    - iv. If the response is incorrect then feedback "Incorrect" is given
5. Once the setup is complete for the initial experiment, participants (or pairs) only need to edit the "tc1" file

#### Running the Experiment:

1. Instructions can be given to participants (see examples for single RT CIT test given to group of students in "Forms" folder.
2. Get participants to open PowerPoint "Images" and get them to select the 5 most memorable Warwick scenes (i.e. WBS students typically pick the image of WBS, etc) – write down the numbers of those images (in bottom right of image)
3. Enter these numbers into the "tc1" file
4. Explain task to participants (i.e. response as fast and accurate to each image, "Yes" to NY Uni, "No" Warwick and other random scenes)
5. Get them to memories the 6 target items – Scenes of New York University – 2-5 mins
  - a. Stress the importance of being able to accurate identify (and response "yes") to these
6. Open "Pair RT CIT"
7. Follow instruction (Enter the test type M (main) or P (practice), participant number, Trial config file i.e. tc1)
  - a. Use the practice round to test people are knowing what to responds to
  - b. Then move onto Main test
8. Once the participant has finished the experiment will close
  - a. Typically takes 15-18 mins to complete

#### Data:

1. Data is saved as .csv files which can be opened in excel
2. See example file to identify what each column is

*Figure A.3. Setup for Partners in Crime similar for Experiments 4*

Department of Psychology: Experiment Set up

### The Polygrapher's Problem - Investigator Effects in the Physiological Concealed Information Test

Researchers: Danni Norman & Kimberley Wade

#### Concealed Information Test Lab Set up (Stimuli Lab C7)

##### Before Participant Arrives

1. Check consent forms and instructions ready
2. Check debrief form ready
3. Check memory and feedback sheet is ready
4. Check electrodes
5. Look at which condition participant is in (guilty or innocent)
6. Open appropriate stimuli video on desktop
7. Check Speaker volume
8. Full screen video
9. Set display to side-by-side 3D ("3D" -> right -> up)
10. Connect glasses and test 3D

##### Participant Arrives

\*Go through video consent form – note: 50 seconds in for INNOCENT stimuli.

\*ATTACH SENSORS

##### Participant Enters Testing Lab

1. Change screen back to 2D
2. Open team viewer and link to the other PC (type 1 -> IACSC8)
3. When investigator starts investigator condition press record on the investigator facing webcam
4. Wait until participant has finished both conditions and then stop biopac acquisition and webcam recording
5. Take participant back to stimuli lab

##### Participant Memory Check & Debrief

\*Go through memory check sheet

2. Give short verbal debrief and offer written debrief to take
3. Answer any questions

*Figure A.4. Setup for What do you know and similar for Fading Memories*

*Experiments 2 and 2 pilot (pg 1/3)*

**Concealed Information Test Lab Set up (Testing Lab C8)****Before Participant Arrives**

1. Check Investigator instructions
2. Locate program to run
3. Move any data files from previous experiment to correct folder
4. Determine whether participant sees PC or Investigator condition
5. Turn on investigator webcam
6. Open Acqknowledge template
7. Go to Media set up and change File Out name to P Number
8. "Check for Hardware" button and select the biopac machine ID
9. Save Acqknowledge template as Participant Name and Experiment – Filename LM(Pnumber)
10. Tidy / untangle electrode cables
11. Check folder of images are filed properly

**Participant Arrives**

[\\*Go through Investigator sheet](#)

**Participant Memory Check & Debrief**

1. Save the physiology data

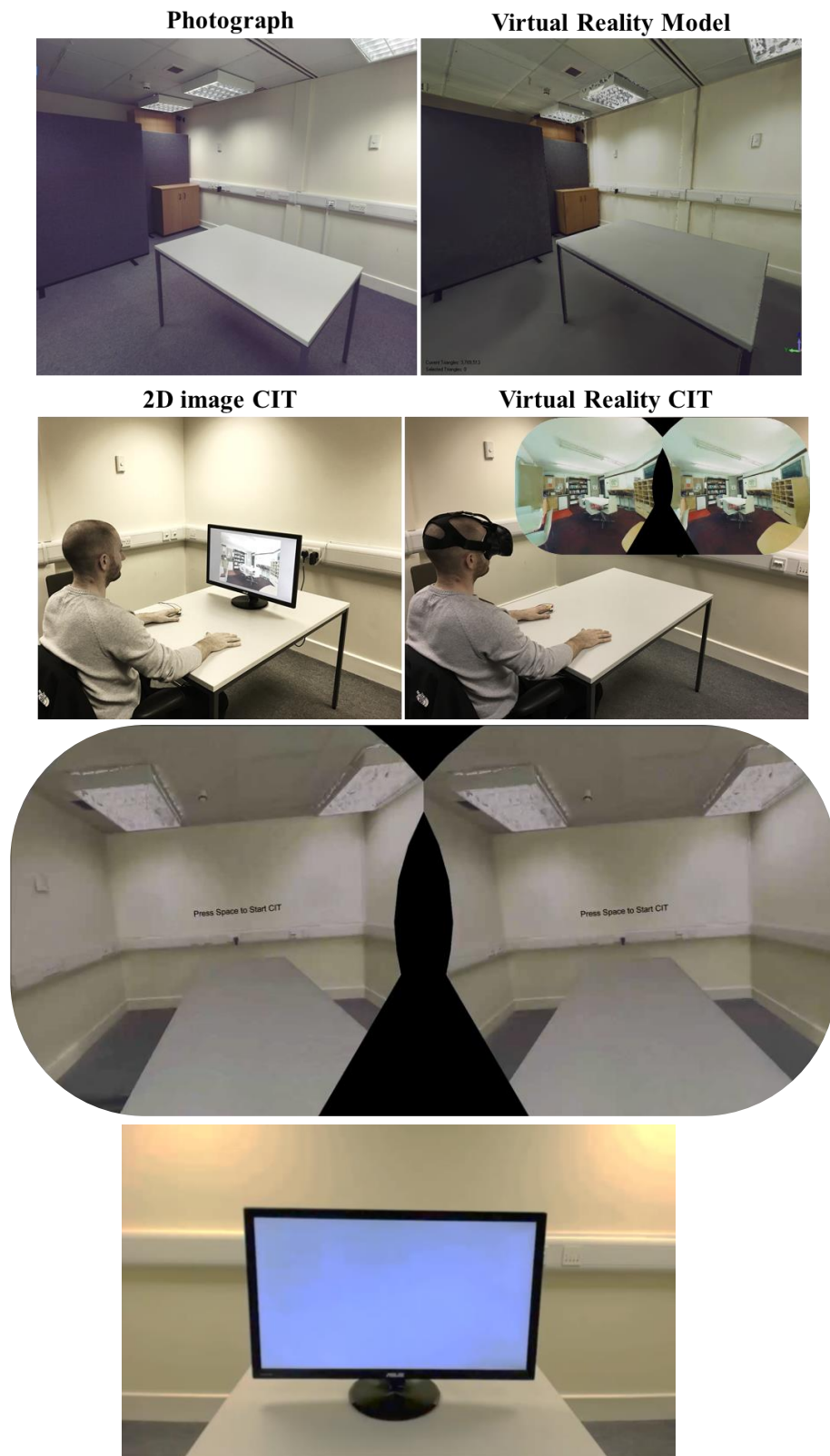
*Figure A.5. Setup for What do you know and similar for Fading Memories*

*Experiments 2 and 2 pilot (pg 2/3)*



*Figure A.6. Setup for What do you know and similar for Fading Memories*

*Experiments 2 and 2 pilot (pg 3/3)*





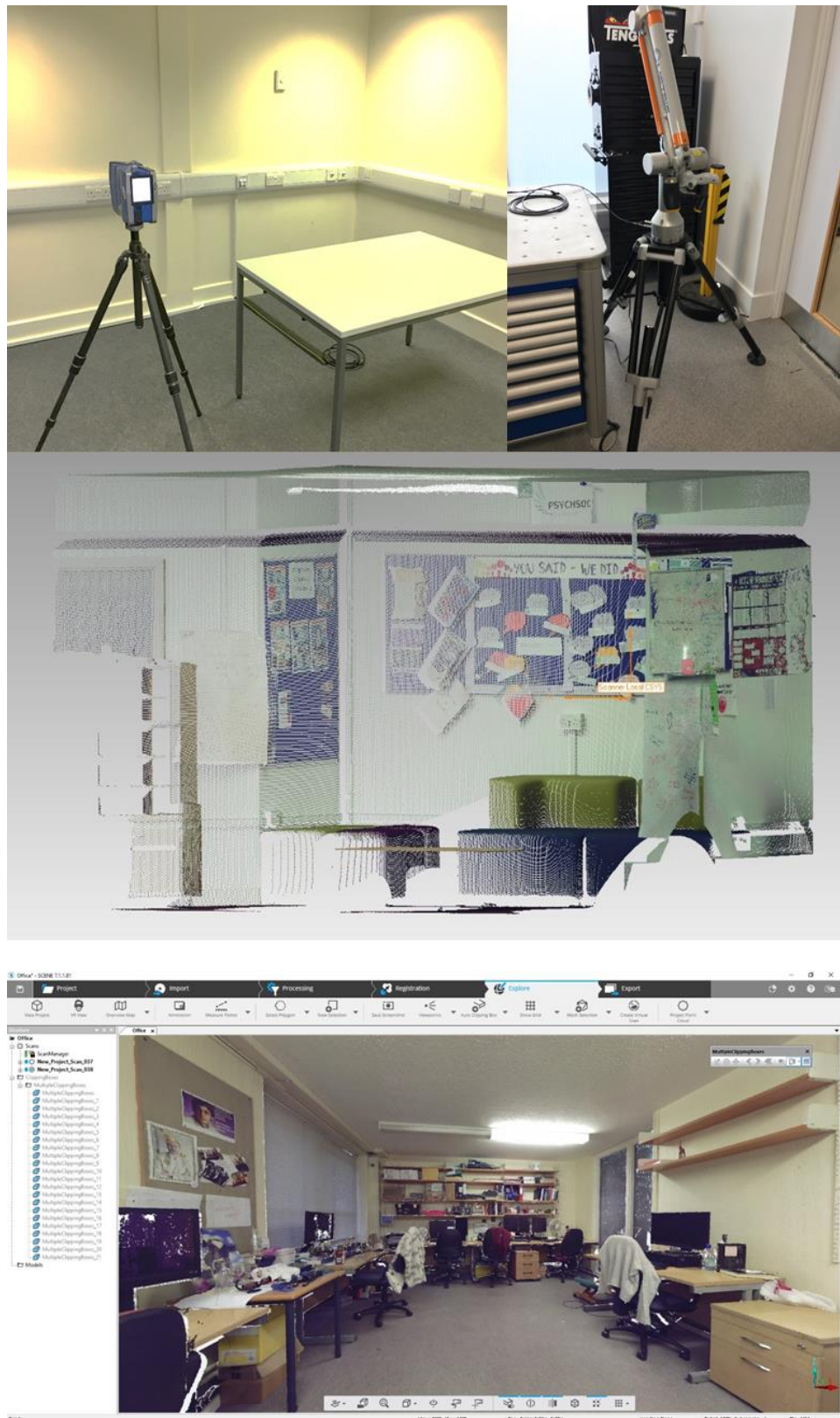


Figure A.8. Setup for Caught Virtually Lying (pg 2/2)





# Psychology Experiment Consent Form

[illegible]

Figure A.10. Consent form for Seen this Scene, Experiment 1 and Partners in Crime Experiments 4

Department of Psychology: Information and Consent Form  
**Reaction Time Deception Detection Task with Mock Crime Stimuli**  
 Researchers: Danni Norman & Derrick Watson

P No:

Thank you for considering participating in this experiment.

This study has two parts with part 2 immediately after part 1.

In Part 1 you'll watch a short 1<sup>st</sup> person perspective video of a mock crime theft. You'll be asked to try and imagine that you were the thief in that scenario and will memorize an alibi prior to taking a reaction time based lie detection test.

In Part 2 you will take the reaction time lie detection test which will involve responding "Yes" or "No" using a keyboard to everyday images presented briefly to you. Some of these responses will require you to lie. You will need to respond as quickly and accurately as possible.

Please read the information below and if you agree, please sign in consent below:

- I have been informed about the nature of the study
- I understand that I have the right to withdraw from the experiment at any time
- I understand that my response data will be securely stored for a minimum of 10 years, in line with the University of Warwick's Research Data Management Policy.
- I understand that if I wish to withdraw my data, I may contact the experimenter quoting my participant ID number. I understand that I should make this request by 01/05/18.
- I will be debriefed at the end and have the opportunity to ask any questions
- I confirm that I am the age of 18 or above
- I understand the information on this sheet and voluntarily consent to participate in the study

Name\*: .....

Date: .....

Signature: .....

Email: (optional) .....@warwick.ac.uk

*\*If you wish to preserve some degree of anonymity, you may use your initials (from the British Psychological Society Guidelines for Minimal Standards of Ethical Approval in Psychological Research)*

.....Experimenter to Tear Here.....

### Participant Demographics

This section will be separated from the consent form above and stored in a difference location.

Participant Number: .....

Gender (optional): .....

Age (optional): .....

Department (optional): .....

*Figure A.11. Consent form and participant information for Upstanding or underhand, Experiments 1-6 and similar to Seen this Scene, Experiment 2-3 and the Unobtrusive measures study*

Department of Psychology: Participant Information Sheet  
 Virtual Reality Lie Detection using the Physiological Concealed Information Test  
 Researchers: Danni Norman & Derrick Watson

### Participant Information Sheet

#### Invitation

You are invited to take part in this study which is being undertaken as part of a PhD degree in Psychology at the University of Warwick. The research has been approved by the Department of Psychology ethics committee. Participation is on a voluntary basis.

#### What will happen

In this study you may be asked to carry out a *fake* crime which will involve stealing an item from a bag from somewhere in the building before returning it to an accomplice (the experimenter) in another location. All of this task will be carried out on the first floor of the Humanities building. There will be no adverse effects if you are caught as this is not a real crime. If you are randomly assigned to the innocent group, you will skip this.

All groups will then take a physiological lie detection test – a bit like a polygraph test in which we will attach sensors to your fingers, wrist and ankle measure your heart rate and skin conductance. During the polygraph test you will be presented with items related to the crime via either a computer monitor or a Virtual Reality Headset. You will be videoed for the purpose of additional analysis. A debrief will be provided at the end. The most innocent scoring participant will each win a £25 Amazon voucher.

#### You will be paid £4 for your participation

#### How long it will take

The experimenter should take no more than 30 minutes of your time.

#### Participant Rights

- You can withdraw from the study at any point and without giving a reason.
- You have the right to request that we withdraw and destroy your data that we have collected from you during this study. In order to do this, please contact the researchers or research supervisor within two weeks of taking part.

#### Confidentiality

Your data will be pseudo anonymized using your participant number and only the researchers named above will be able to link your participant number to your name. The identifying information provided on the consent form will be stored separately from your data. Your data will be stored for a minimum of 10 years to allow inspection of the anonymized data upon request. This is consistent with the University of Warwick's Research Data Management Policy. Upon completion of the experimenter's PhD studies (May 2020) storage of the data will be reviewed.

#### Using your data

We expect to finish data collection for this study by 1<sup>st</sup> January 2019. Following this the anonymized data will be analyzed and reported in the experimenter's PhD thesis which will be available to the University of Warwick. There may also be publication of the work as either a scientific journal paper, conference presentation or internal presentation. The work may also be provided to other researchers and published on open science data repositories. In all cases, only anonymized data will be presented or supplied, and your data will not be personally indefinable.

#### Further questions

If you have any further questions, then please ask now. If you are happy to continue, please read and sign the consent form.

*Figure A.12. Consent form and participant information for Caught Virtually Lying and similar to Partners in Crime, Experiment 1-3 & 6, What do you know and Fading Memories Experiment (pg 1/2)*

P.No.

Department of Psychology: Consent Form  
Virtual Reality Lie Detection using the Physiological Concealed Information Test  
Researchers: Danni Norman & Derrick Watson

### Consent Form

I have read the Participant Information Sheet for this study *"Virtual Reality Lie Detection using the Physiological Concealed Information Test"* and have no further questions regarding the experiment procedure  
No ☐ Yes ☐

I understand that physiological recordings will be taken and that this will involve the placement of sensors on my fingers, wrist and ankle  
No ☐ Yes ☐

I understand that I may be instructed to carry out a fake crime which will involve stealing an item from a bag from somewhere in the building before returning it to an accomplice (the experimenter) in another location  
No ☐ Yes ☐

I permit the audio-video recording of today's experiment and agree to storage of the recording for up to 10 years or until the recording is no longer needed. Note: if the data are published in a scientific journal, the journal may require us to keep the raw data several years after publication. Your personal information (e.g., name) will never be used in any dissemination  
No ☐ Yes ☐

Can we use video-audio data in possible presentations as an illustration of the above scientific research, in scientific and educational publications?  
No ☐ Yes ☐

After completion of the study, a table will be sent to all participants (blind-copied) indicating: a) whether you would have been categorized as guilty or non-guilty, and b) How you compared to other participants. The data in the table will be anonymized – to find your result you will need to remember the date and time when you took part. From the ranking, the most innocent scoring participants will win a £25 Amazon voucher.

- Would you like to be included in the ranking table?  
No ☐ Yes ☐

Please read the information below and if you agree, sign in consent below:

- I have been informed about the nature of the study
- I understand that I have the right to withdraw from the experiment at any time
- I understand that my response data will be securely stored for a minimum of 10 years, in line with the University of Warwick's Research Data Management Policy.
- I understand that if I wish to withdraw my data, I may contact the experimenter quoting my participant ID number. I understand that I should make this request within two weeks of today.
- I will be debriefed at the end and have the opportunity to ask any questions
- I confirm that I am the age of 18 or above
- I understand the information on this sheet and voluntarily consent to participate in the study

|            |  |
|------------|--|
| Name*:     | Date:                                    |
| Signature: | Email: (If different from Warwick email) |

\*If you wish to preserve some degree of anonymity, you may use your initials (from the British Psychological Society Guidelines for Minimal Standards of Ethical Approval in Psychological Research)

*Figure A.13. Consent form and participant information for Caught Virtually Lying and similar to Partners in Crime, Experiment 1-3 & 6, What do you know and Fading Memories Experiment (pg 2/2)*

## Demographics

Department of Psychology: Participant Demographics  
 Partners in Crime - Shared Information and Paired Testing in the Concealed Information Test  
 Researchers: Danni Norman & Derrick Watson

| Participant No | Pair No | Department (optional) | Age (optional) | Gender (optional) | Dominant Hand |
|----------------|---------|-----------------------|----------------|-------------------|---------------|
| 1              |         |                       |                |                   | R / L         |
| 2              |         |                       |                |                   | R / L         |
| 3              |         |                       |                |                   | R / L         |
| 4              |         |                       |                |                   | R / L         |
| 5              |         |                       |                |                   | R / L         |
| 6              |         |                       |                |                   | R / L         |
| 7              |         |                       |                |                   | R / L         |
| 8              |         |                       |                |                   | R / L         |
| 9              |         |                       |                |                   | R / L         |
| 10             |         |                       |                |                   | R / L         |
| 11             |         |                       |                |                   | R / L         |
| 12             |         |                       |                |                   | R / L         |
| 13             |         |                       |                |                   | R / L         |
| 14             |         |                       |                |                   | R / L         |
| 15             |         |                       |                |                   | R / L         |
| 16             |         |                       |                |                   | R / L         |
| 17             |         |                       |                |                   | R / L         |
| 18             |         |                       |                |                   | R / L         |
| 19             |         |                       |                |                   | R / L         |
| 20             |         |                       |                |                   | R / L         |
| 21             |         |                       |                |                   | R / L         |
| 22             |         |                       |                |                   | R / L         |
| 23             |         |                       |                |                   | R / L         |
| 24             |         |                       |                |                   | R / L         |
| 25             |         |                       |                |                   | R / L         |

*Figure A.14. Demographics form for Partners in crime and similar for all other studies*

## Instructions

Department of Psychology: Experimenter Instructions  
Reaction Time Deception Detection Task with Warwick Stimuli  
Researchers: Danni Norman & Derrick Watson

1. **Consent Forms** – write the participant number in the top right-hand box on each sheet

### 2. Your Mission!

You are an undercover spy from Warwick University infiltrating New York University to steal their latest research! New York University Security suspects a mole and are therefore requiring all staff to sit a 'lie detection test.' Their 'lie detection test' assumes that spies will be slower to recognise and make more mistakes when they respond to images of New York University. They also hoping to catch spies that accidentally respond "Yes" to images of Warwick University who they believe are the prime suspects.

**Warwick University Scenes** that you will recognise but must lie and respond "No" to:



**New York University Scenes** to memorise and response "Yes" to:



Images also available in the folder in front of you – named **Images.pdf**

*Figure A.15. Instructions for Seen this Scene, Experiments 1 & 3 and similar to Partners in Crime, Experiment 4-5 and Upstanding or underhand, Experiments 1-4 (pg 1/2)*

### 3. Reaction Time Lie Detection Test

During the 'Lie Detection Test' you will be shown a series of scenes. Many of these items will be unfamiliar to you except the ones relating to the crime you just 'committed' (in the video) and the Alibi items you have just memorised.

Each image will appear for around 1 second with less than a second gap between them. Using the keyboard, please respond to these images as fast as you can making with as few errors as possible! (Images will appear either on the top or bottom half of the screen – just ignore this.)

The question to bear in mind for every image is: ***"Do you recognise this item?"***

For all **unfamiliar** scenes respond honestly with **"No"** using the **"Right Arrow"** Key.

For **Warwick** scenes respond deceptively with **"No"** using the **"Right Arrow"** Key.

For **New York** scenes respond deceptively with **"Yes"** using the **"Left Arrow"** Key.



### 4. Practice Test

- We'll now complete a practice test containing 90 items. In this practice test only, a message will appear if you respond too slowly or press the wrong key – If this happens don't worry and just carry on.
- After this practice there will be a short break including an opportunity for questions.
- Please wait for further instructions from the experimenter

### 5. Main Test

- The main test is exactly the same but there will be 5 blocks with a 5 seconds break between each one.
- If the experiment crashes, then raise your hand and the experimenter will come over
- Please don't disturb the other participants. This includes hitting the keyboard too hard
- At the end of the test please wait quietly for the experimenter before starting the final part of the experiment
- Please wait for further instructions from the experimenter

### 6. Debrief

A short verbal debrief will be provided along with a full written debrief at the end. Questions are welcome.

*Figure A.16. Instructions for Seen this Scene, Experiments 1 & 3 and similar to*

*Partners in Crime, Experiment 4-5 and Upstanding or underhand, Experiments 1-4*

*(pg 2/2)*

Department of Psychology: Experimenter Instructions  
**Reaction Time Deception Detection Task with Mock Crime Stimuli**  
 Researchers: Danni Norman & Derrick Watson

**1. Consent Forms**

**2. Experiment Instructions Part 1**

Your primary task in this study will be to play the role of a criminal during a lie detection test. You'll need to aim to appear as innocent as possible by lying about any information you will soon recognition from the crime video.

**3. Video Instructions**

You'll now watch a three minute, 1st person perspective, mock crime video, of a thief, (you!) stealing a bicycle from outside the humanities building on campus.

It's really important you pay attention throughout and really try and imagine yourself as the person whose perspective your seeing in the video. There will also be a memory test at the end.

**4. Watch Video**

Please plug in your headphones and check the sound works. Then please wait for the experimenter to ask you to start the video as everyone will need to start at the same time.

**5. Post Video Instructions**

Now imagine you have been contacted by the local police station and have been informed that you are potential suspects in a recent crime. They explain that during their investigation they would like to administer a lie detection test to all potential suspects to help narrow down their investigation. The lie detection test will use the crime images below which you should now recognize from the video:

Images you will recognize:

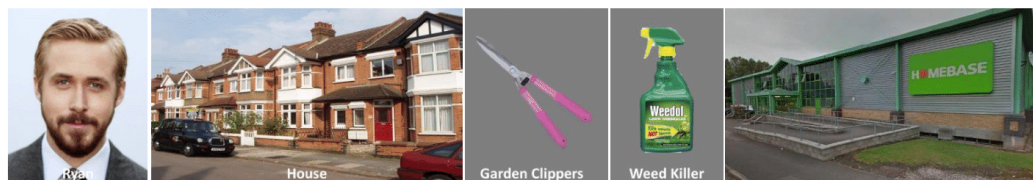


Images also available in the folder in front of you – names [Images.pdf](#)

**6. False Alibi**

Before you go for the lie detection test you prepare an alibi. You have asked your good friend Ryan to be a false alibi for the time of the events and you have told the police this alibi story:

*"It wasn't me who committed that crime as I was with my friend, **Ryan** at his **home** gardening all day. We only left the house to buy some **garden clippers** and **weed killer** from a nearby **DIY store**."*



Images also available in the folder in front of you – names [Images.pdf](#)

*Figure A.17. Instructions for Upstanding or underhand, Experiments 2 and similar to Seen this Scene, Experiments 2 (pg 1/2)*



### 7. Reaction Time Lie Detection Test

During the 'Lie Detection Test' you will be shown a series of items of objects and scenes. Many of these items will be unfamiliar to you except the ones relating to the crime you just 'committed' (in the video) and the Alibi items you have just memorised.

Each image will appear for around 1 second with less than a second gap between then. Using the keyboard, please respond to these images **as fast as you can making with as few errors as possible!** (Images will appear either on the top or bottom half of the screen – just ignore this.)

The question to bear in mind for every image is: *"Do you recognise this item?"*

For all **unfamiliar** images respond honestly with **"No"** using the **"Right Arrow"** Key.

For **crime** related images respond deceptively with **"No"** using the **"Right Arrow"** Key.

For **fake alibi** images respond deceptively with **"Yes"** using the **"Left Arrow"** Key.



### 8. Practice Test

- We'll now complete a practice test containing 90 items. In this practice test only, a message will appear if you respond too slowly or press the wrong key – If this happens don't worry and continue
- After this practice there will be a short break including an opportunity for questions.
- Please wait for further instructions

### 9. Main Test

- The main test is exactly the same but there will be 450 images with a 5 seconds break after every 90 images.
- If the experiment crashes, then raise your hand and the experimenter will come over
- Please don't disturb the other participants. This includes hitting the keyboard too hard
- At the end of the test please wait quietly for the experimenter before starting the final part of the experiment
- Please wait for further instructions

### 10. Debrief

A short verbal debrief will be provided along with a full written debrief at the end. Questions are welcome.

*Figure A.18. Instructions for Upstanding or underhand, Experiments 2 and similar to*

*Seen this Scene, Experiments 2 (pg 2/2)*

Department of Psychology: Experimenter Instructions  
Reaction Time Deception Detection Task with Alibi  
Researchers: Danni Norman & Derrick Watson

### 1. Consent Forms

### 2. Instructions

Your primary task in this study will be to play the role of an innocent suspect during a lie detection test.

Now imagine you have been contacted by the local police station and have been informed that you are potential suspects in a recent crime. They explain that during their investigation they would like to administer a lie detection test to all potential suspects to help narrow down their investigation. The lie detection test will have images relating to the crime which, as you are innocent, you will not recognize

### 3. Alibi

During the time of the crime you were with your friend Ryan and have therefore told the police this: *"It wasn't me who committed that crime as I was with my friend, **Ryan** at his **home** gardening all day. We only left the house to buy some **garden clippers** and **weed killer** from a nearby **DIY store**."*



Figure A.19. Instructions for Upstanding or underhand, Experiments 6 (pg 1/2)

#### 4. Reaction Time Lie Detection Test

During the 'Lie Detection Test' you will be shown a series of items of objects and scenes. Many of these items will be unfamiliar to you except the ones relating to the Alibi items you have just memorised above.

Each image will appear for around 1 second with less than a second gap between them. Using the keyboard, please respond to these images **as fast as you can making with as few errors as possible!** (Images will appear either on the top or bottom half of the screen – just ignore this.)

The question to bear in mind for every image is: *"Do you recognise this item?"*

For all **unfamiliar** images respond with **"No"** using the **"Right Arrow"** Key.

For **fake alibi** images respond with **"Yes"** using the **"Left Arrow"** Key.



#### 5. Practice Test

- We'll now complete a practice test containing 90 items. In this practice test only, a message will appear if you respond too slowly or press the wrong key – If this happens don't worry and continue
- After this practice there will be a short break including an opportunity for questions.
- Please wait for further instructions

#### 6. Main Test

- The main test is exactly the same but there will be 450 images with a 5 seconds break after every 90 images.
- If the experiment crashes, then raise your hand and the experimenter will come over
- Please don't disturb the other participants. This includes hitting the keyboard too hard
- At the end of the test please wait quietly for the experimenter before starting the final part of the experiment
- Please wait for further instructions

#### 7. Debrief

A short verbal debrief will be provided along with a full written debrief at the end. Questions are welcome.

*Figure A.20. Instructions for Upstanding or underhand, Experiments 6 (pg 2/2)*

## Experimenter Instruction Sheet

### 1. Overview and Consent

- Following study overview (Participant Information) participant is invited to give consent

### 2. Attached Electrodes

- If you are both comfortable I'll now attach two pairs of electrodes to allow them to dry.
- One pair of electrodes will be attached to your 1<sup>st</sup> and 2<sup>nd</sup> finger on your non-dominant hand and will measure skin conductance which is a measure of sweat on a small scale.
- The other pair of electrodes attach to your dominant hand wrist and the opposite ankle and will measure heart rate.
- If you do not wish for any particular electrodes to be attached, then please say now.

### 3. Crime Video

- You'll both **now watch** two separate, but overlapping, mock crime video where you will both be hired by a criminal mastermind to steal a very valuable prototype device and related material from a secret lab that belongs to a tech company.
- You will see **your partner** in the video and they will see you. When you are together you will obviously see the same things but when you split up to do your separate tasks you will not see what your partner is doing and equally they will have no knowledge of what you're doing.
- It's really important you **pay attention** throughout and really try and imagine yourself as the people whose perspective you're seeing in the video. Try and imagine that your partner in the video is your real-life partner in this study. There will be a memory test at the end.
- You will watch the video's standing back to back but **PLEASE do not look** at each other's videos as this is key to my study. Please don't communicate with each other and it is vital that you do not see each other's videos!
- I'll now set up the videos. During the video you'll be left in this room alone with lights off and door shut.
- When the video has finished, or if there are any issues, please press the switch on the table and I'll return.

### 4. Post Video Instructions

- Before I take suspect A / you both next door for the lie detector test here is a **summary** sheet of 1) the crime items that both of you know, 2) the items that only you know.

*Figure A.21. Instructions for Partners in Crime, Experiments 1-3 (pg 1/3)*

- **Now imagine** you've both been contacted by the police and they have informed you that you are now both suspects in this crime and will therefore take a lie detection test
- In a minute I'll take one/both of you to the police station (next door) to take the test.
- **Your task** during the lie detection test is to appear as innocent as possible by denying any knowledge about the crime. **If EITHER** of you are detected as guilty then you are both guilty. Therefore it's not just you but your partner that you need to lie for. Qs?

## 5. Take participants to appropriate labs

- Suspect B, please can you wait in this cubicle and I will test you after suspect A.

## 6. "Interview"

- Hello, **I'm the officer** in charge of this investigator. We're grateful to you and your partner for coming into the police station today to answer some questions.
- So let me explain why we've brought you both in.
- **Within the last** few days two highly professional thieves stole a very valuable device and some other related material from a secret lab belonging to a tech company.
- We have reason to believe that the thieves were hired to do this by a **3rd person** who provide them with everything they needed for the heist. We know that one of the pair later met this person to hand over the items to be sold probably on the black market.
- Now we know that you and your partner have a **history of carrying** out these high profile thefts. So why don't you both save us all a lot of time and confess to this crime. Did you carry out this theft?... OK, well we'll get on with the lie detection test then

## 7. CIT procedure

- I'll explain how it's going to work. We've take **9 specific details** of the crime and used these to create 9 questions that we are certain that at least one of you will recognize the answer to. Any recognition of these items will be treated as guilt. [\[SHOW\]](#)
- Each question is phrased as, "**Do you recognize any of the following...**" you only need to think the word **No** when the option is presented on the screen.
- There will be a pause after each item and overall the test will take 11 minutes.

## 8. Attach the electrodes

- Please keep your palm faced down on this pad and arms on the desk. I'd really appreciate it if you could refrain from **fidgeting** or moving your hands throughout the procedure – fidgeting doesn't help you beat the test, it just results in poor data
- Please **do not communicate** with each other throughout.
- Once the test has finished or if you need any assistance then press this **button**.

*Figure A.22. Instructions for Partners in Crime, Experiments 1-3 (pg 2/3)*



Department of Psychology: Crime Summary Sheet  
Partners in Crime - Shared Information and Paired Testing in the Concealed Information Test  
Researchers: Daniel Newman & Derrick Watson

**Suspect 1 AND 2**  
Images **both you and your partner** will know about / recognise



Crowbar



Mike



Lab E

**Suspect 1**  
Crime item **only you** know above/recognise (i.e. **your partner doesn't know**)



Shaving Foam



Bolt Cutters



Car Park

**Suspect 2**  
Crime item **only you** know above/recognise (i.e. **your partner doesn't know**)



Blueprints



Brain



Office C

Figure A.23. Instructions for Partners in Crime, Experiments 1-3 (pg 3/3)

## Experimenter Instruction Sheet

### 1. Overview and Consent

- P read “Participant Information Sheet” and then is invited to give consent
- Assign “A” and “B” to participants

### 2. Crime Video

- You’ll both **now watch** two separate, but overlapping, mock crime video where you will both be hired by a criminal mastermind to steal a very valuable prototype device and related material from a secret lab that belongs to a tech company.
- You will see **your partner** in the video and they will see you. When you are together you will obviously see the same things but when you split up to do your separate tasks you will not see what your partner is doing and equally they will have no knowledge of what you’re doing.
- It’s really important you **pay attention** throughout – there will be a memory check at the end! - and really try and imagine yourself as the people whose perspective you’re seeing in the video. Try and imagine that your partner in the video is your real-life partner in this study.
- You will watch the video’s standing back to back but **PLEASE do not look** at each other’s videos as this is key to my study. Please don’t communicate with each other and it is vital that you do not see each other’s videos!
- During the video you’ll be left in this room alone with lights off and door shut.
- When the video has finished, or if there are issues, please press the switch on the table and I’ll return.

### 3. Post Video Instructions

- Before I take you both next door for the lie detector test here is a **summary** sheet of the crime items that you both know (sheet 1) and the items that only you know (sheet 2).
- **Now imagine** you’ve both been contacted by the police and they have informed you that you are now both suspects in this crime and will therefore take a lie detection test
- **Your task** during the lie detection test is to appear as innocent as possible by denying any knowledge about the crime. **If EITHER** of you are detected as guilty then you are both guilty. Therefore, it’s not just you but your partner that you need to lie for. Qs?

### 4. Fake Alibi

- So, **to help you lie successfully**, you have asked your good friend Ryan to be a fake alibi for the time of the events and you have told the police this story *“It wasn’t me who committed the crime as I was with my friend, **Ryan** at his **home** gardening all day. We only left the house to buy some **hedge clippers** from a nearby DIY store, **Homebase**.”*
- The police have **incorporated your alibi** into their reaction time lie detection test which they will give you and therefore to appear innocent in the test you will need to respond “Yes” to the images of Ryan, his house, some hedge clippers and Homebase (Give Alibi sheet to Ps)

### 5. Take participants to the Testing room

Figure A.24. Instructions for Partners in Crime, Experiments 6 (pg 1/6)

## 6. “Police Interview”

- Hello, I’m the officer in charge of this investigator. I’m grateful to you and your partner for coming into the police station today to answer some questions. So let me explain why we’ve brought you both in.
- Within the last few days two highly professional thieves stole a very valuable device and some other related material from a secret lab belonging to a tech company.
- We have reason to believe that the thieves were hired to do this by a 3rd person who provide them with everything they needed for the heist. We know that one of the pair later met this person to hand over the items to be sold probably on the black market.
- Now we suspect, based on your previous criminal history, that you and your partner carried out this crime! So why don’t you save us some time and confess. Did you carry out this theft?... OK, well we’ll get on with the lie detection test and I’ll explain how it’s going to work

## 7. Reaction Time Lie Detection Test

- You will both take a reaction time-based computer lie detection test together / one at a time. During the lie detection test you will be shown a series of images of objects and scenes. Many of these images will be unfamiliar to you except the ones relating to the crime and the alibi your provided.
- Each image will appear for around 1 second with less that a second gap between then. Using the keyboard, respond to these images as fast as you can making with as few errors as possible!
- Consider this question for each image: “Do you recognise this item?”
  - For all unfamiliar images respond honestly with “No”
  - For crime related images respond deceptively with “No”
  - For fake alibi images respond deceptively with “Yes”
- Suspect A: Use the LEFT for YES and the RIGHT for NO
  - Suspect B: Use the Z for YES and C for NO
- Does that make sense? Don’t worry, there will be a practice before the main test starts.

8. (If separate condition) Suspect B, please can you wait outside in the waiting area and I will test you after suspect A.

## 9. Practice Test

- We’ll now complete a short practice test. In this practice test only, a message will appear if you respond too slowly or press the wrong key – If this happens don’t worry and continue
- After this practice there will be a short break including an opportunity for questions

## 10. Main Test

- The main test is exactly the same but will be longer
- If the experiment crashes or you’ve finished the press this button to signal me
- (If together) Don’t hit the keyboard too hard as this will distract your partner
- Please do not communicate with each other throughout.

## 11. (If separate condition) Swap Participants

## 12. Debrief

*Figure A.25. Instructions for Partners in Crime, Experiments 6 (pg 2/6)*



Department of Psychology: Experimenter Instructions RTCIT  
Partners in Crime - Shared Information and Paired Testing in the Concealed Information Test - RTCIT  
Researchers: Danni Norman & Derrick Watson

## Instruction Sheet Suspect 1

### 1. Consent Forms

### 2. Experiment Instructions Part 1

Your primary task in this study will be to play the role of a criminal during a lie detection test. You will work with your partner to carry out a crime and then try and beat the lie detection test. You'll need to aim to appear as innocent as possible by lying about any information you will soon recognition from the crime video.

### 3. Video Instructions

You'll now watch an 8 minute, 1<sup>st</sup> person perspective, mock crime video during which you are to imagine as best as possible that you are the person in the video carrying out the tasks.

**It's really important you pay attention throughout and really try and imagine yourself as the person whose perspective your seeing in the video.  
There will also be a memory test at the end.**

Also, you need to imagine as best as possible that the criminal partner in the video is in fact your participant partner – they will be watch the video from the other criminal's perspective and therefore will see different events to you – please do not discuss what you've seen until after the experiment!

### 4. Watch Video

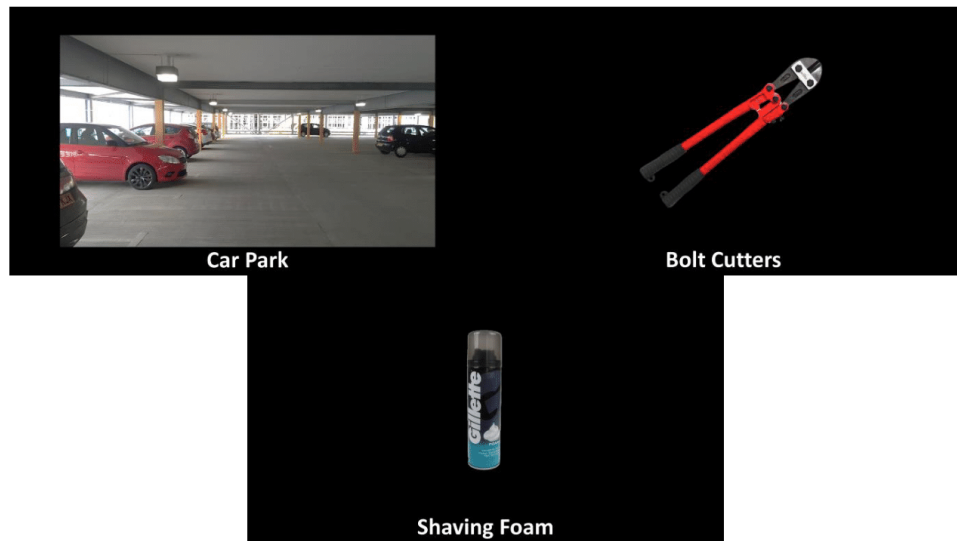
Please plug in your headphones and check the sound works. Then please wait for the experimenter to ask you to start the video as everyone will need to start at the same time.

*Figure A.26. Instructions for Partners in Crime, Experiments 6 (pg 3/6)*

### 5. Post Video Instructions

Please now imagine you have been contacted by the local police station and have been informed that you are potential suspects in a recent crime. They explain that during their investigation they would like to administer a lie detection test to all potential suspects to help narrow down their investigation. The lie detection test will use some of the crime images below which you should now recognise from the video:

Images only you will recognise (your partner will not): (p1)



Images both you and your partner will recognise:

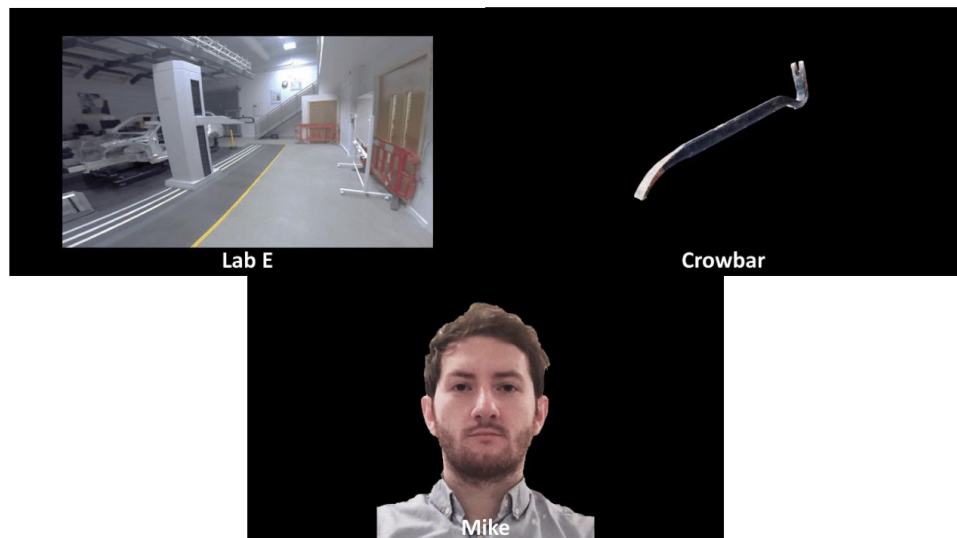


Figure A.27. Instructions for Partners in Crime, Experiments 6 (pg 4/6)

## 6. False Alibi

Before you go for the lie detection test you prepare an alibi. You have asked your good friend Ryan to be a false alibi for the time of the events and you have told the police this alibi story:

*“It wasn’t me who committed that crime as I was with my friend, **Ryan** at his **home** gardening all day. We only left the house to buy some **garden clippers** from a nearby **DIY store**.”*

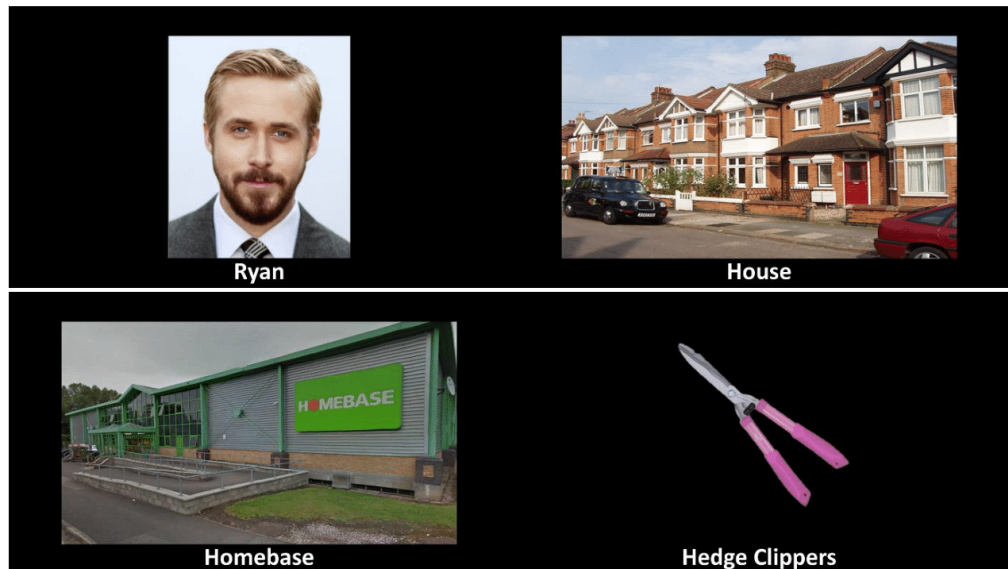


Figure A.28. Instructions for Partners in Crime, Experiments 6 (pg 5/6)

## 7. Reaction Time Lie Detection Test

During the 'Lie Detection Test' you will be shown a series of items of objects and scenes. Many of these items will be unfamiliar to you except the ones relating to the crime you just 'committed' (in the video) and the Alibi items you have just memorised.

Each image will appear for around 1 second with less than a second gap between then. Using the keyboard, please respond to these images **as fast as you can making with as few errors as possible!**

Consider this question for each image: ***"Do you recognise this item?"***

For all **unfamiliar** images respond honestly with **"No"**

For **crime** related images respond deceptively with **"No"**

For **fake alibi** images respond deceptively with **"Yes"**

**Suspect 2: Use Z for Yes and C for NO**

## 8. Practice Test

- We'll now complete a short practice test. In this practice test only, a message will appear if you respond too slowly or press the wrong key – If this happens don't worry and continue
- After this practice there will be a short break including an opportunity for questions - Please wait for further instructions

## 9. Main Test

- The main test is exactly the same but will be longer
  - If the experiment crashes, then raise your hand and the experimenter will come over
  - Please don't disturb the other participants. This includes hitting the keyboard too hard
  - At the end of the test please wait quietly for the experimenter before starting the final part of the experiment

## 10. Debrief

*Figure A.29. Instructions for Partners in Crime, Experiments 6 (pg 6/6)*

**The Polygrapher's Problem - Investigator Effects in the Physiological Concealed Information Test**

Researchers: Danni Norman &amp; Kimberley Wade

**- ATTACH SENSORS**

This is part 1 of the study. You may ask any questions at this stage, but please note that when you go next door for the interview in part 2, you'll need to play the role of an innocent/guilty suspect and we kindly request that you only ask experiment related questions if necessary.

**You have been allocated to the innocent/guilty condition.**

The other experimenter next door will play the role of criminal investigator and isn't allowed to know whether you are guilty or innocent. Your primary task will be to appear as innocent as possible by showing the investigator that you have no knowledge of the crime. This may involve directly lying or trying not to appear suspicious.

You'll now watch a short video which relates to your suspect role. During the video, you are to imagine as best as possible that you are the person in the video carrying out the tasks.

**It's really important you pay attention throughout and really try and imagine yourself as the person whose perspective you're seeing in the video. There will also be a memory test at the end of the study.**

I will leave you in the room with the lights off and door shut. When the video has finished please press this switch on the table and I will return to provide further instruction.

If there are any issues during the video I will be outside. To stop the video just press SPACE – though, ideally the video should run uninterrupted.

- *Provide 3D glasses*
- *Ask to stand with legs touching table*
- *Ask to press spacebar once you have left the room*

**Video runs.**

-----xx(3 mins)xx-----

Any questions?

**Post Video Instructions**

I want you to now imagine you have been contacted by the local police station and have been informed that you are a potential suspect in a recent crime. They explain that during their investigation they would like to administer a lie detection test to all potential suspects to help narrow down their investigation.

When you are ready you will be taken next door where you will meet the investigator and take the lie detection test. Until you're brought back into this room by the experimenter you are to remain in role.

**Remember it's really important that you try and remain in role (the investigator will be) and DO NOT let the investigator know whether are guilty or innocent – They will be trying to work this out!**

The investigator will explain the rest. Any questions?

- *Take subject next door*

*Figure A.30. Instructions for What do you know, Experiment 1-2 (pg 1/3)*

Department of Psychology: Guilty Participant Instructions

**The Polygrapher's Problem - Investigator Effects in the Physiological Concealed Information Test**

Researchers: Danni Norman & Kimberley Wade

This is part 1 of the study. You may ask any questions at this stage, but please note that when you go next door for the interview in part 2, you'll need to play the role of an innocent/guilty suspect and we kindly request that you only ask experiment related questions if necessary.

**You have been allocated to the guilty condition.**

The other experimenter next door will play the role of criminal investigator and isn't allowed to know whether you are guilty or innocent. Your primary task will be to appear as innocent as possible by showing the investigator that you have no knowledge of the crime. This may involve directly lying or trying not to appear suspicious.

You'll now watch a short video which relates to your suspect role. During the video, you are to imagine as best as possible that you are the person in the video carrying out the tasks.

**It's really important you pay attention throughout and really try and imagine yourself as the person whose perspective you're seeing in the video. There will also be a memory test at the end of the study.**

I will leave you in the room with the lights off and door shut. When the video has finished please press this switch on the table and I will return to provide further instruction.

If there are any issues during the video I will be outside. To stop the video just press SPACE – though, ideally the video should run uninterrupted.

*Figure A.31. Instructions for What do you know, Experiment 1-2 (pg 2/3)*

## Department of Psychology: Investigator Instructions

## The Polygrapher's Problem - Investigator Effects in the Physiological Concealed Information Test

Researchers: Danni Norman &amp; Kimberley Wade

*(Conversation style)*

- ☐ Hello, I am the criminal investigator conducting this procedure today.
- ☐ Thank you for coming in and helping us out with our investigation.
- ☐ You might be wondering why we've invited you in today so I'll explain the situation.

**The Crime**

- ☐ Within the last few days someone stole a **valuable item** from a bag **somewhere** on University Campus.
- ☐ Although the bag was padlocked the thief managed to **disable** the lock and steal the item inside
- ☐ Unfortunately, the CCTV camera at the **place** where the item was stolen from was **masked** by the thief, so we don't know who the thief is.
- ☐ Thankfully a witness later saw the thief and an **accomplice** exchanging the stolen item for cash and we have a description of what the thief looks like.
- ☐ We also now know **when** and **where** this exchange occurred and as we have the accomplice in custody we know how much was **paid** for the item.
- ☐ Does this make sense?

**So why are you here?**

- ☐ Unfortunately, you, along with a few others, match the witness's description of the suspect.
- ☐ To narrow down our investigation, we are administering a lie detection test to all suspects
- ☐ Firstly we'd like to offer you the opportunity to confess – so were you the thief in this crime?
- ☐ OK so as you are claiming innocence I'm sure you won't mind taking the lie detector test?

**OK so we'll now attach the sensors** *Explain and attach Respiration first – Demo if needed*

- ☐ Please keep your palms faced down on these pads and sit close to the wall with arms on the desk.
- ☐ I'd really appreciate it if you could refrain from fidgeting or moving your hands throughout the procedure – fidgeting doesn't help you beat the test, it just results in poor data which we don't want
- ☐ The test will take around 15 minutes. There will be a long pause after each item is present – Don't worry you'll get used to them, I know I have...

**I'll now describe how the procedure will work**

- ☐ We've been very careful to keep the specific details of the crime secret and have used these details to create 8 questions which we are certain only the guilty suspect will recognize the answer to.  
[Show them and briefly read each one, make clear that there are questions with 5 possible options, presented in a sequence and that only one is the correct crime item in each question]
- ☐ As each question is phrased as, **Do you recognise** this particular item as the one etc, you only need to respond verbally with **No**. Please respond loud enough for the webcam to pick up.
- ☐ Any questions so far whilst I just **check the sensors are working?**
- ☐ [PC condition] Once you've **finished** or need any **assistance** then press this **button** [indicate bell]
- ☐ Are you ready to proceed? [Start Procedure]

*Figure A.32. Instructions for What do you know, Experiment 1-2 (pg 3/3)*

## Experimenter Instruction Sheet

### 1. Participant Information and Consent

- Following study overview (Participant Information) participant is invited to give consent
- You are in the \_\_\_\_\_ condition [If VR then sett up Phys Data Input File]

### 2. [IF GUILTY CONDITION] Fake Crime Instructions

- **Imagine** that we are both thieves who have come onto Warwick campus to steal some valuable items.
- Whilst walking around I **have identified** an unattended bag in an office that looks like it has a tablet computer inside. I want you to steal the tablet and then meet me in the psychology common room.
- Here's the plan: (show them the map)
  1. Head left from the start point and find the open **office H122**
  2. Knock on the door and **tell the person** inside that: "Danni has asked that I wait for her in here"
  3. Sit at the desk in the corner **with the handbag** on for about a minute
  4. **Steal the tablet** from the handbag and leave saying: "Oh actually Danni said the common room"
  5. Wait for me in the psychology **common room** (I might be about a minute)
- There will be people in the office but please bear in mind that this is **not a real crime**. However, try and not be caught.

### 3. Post Crime Instructions

- Imagine you've both been **contacted by the police** a few days later.
- They tell you that someone stole an item from a bag somewhere on University campus before handing it over to an accomplice in another location.
- You, along with a few others, match the **description of a witness's** present at the crime and therefore, are now a suspect.
- You will therefore **undergo a lie detection** test which will test whether you recognise any details about the crime.

*Figure A.33. Instructions for Caught Virtually Lying (pg 1/3)*



#### 4. Attached Electrodes

- If you are comfortable, I'll **now attach two pairs of electrodes** to allow them to settle.
- One pair of electrodes will be attached to your 1<sup>st</sup> and 2<sup>nd</sup> finger on your non-dominant hand and will measure skin conductance which is a measure of sweat on a small scale.
- The other pair of electrodes attach to your dominant hand wrist and the opposite ankle and will measure heart rate.
- If you do not wish for any particular electrodes to be attached, then please say now.
- Please keep your palm faced down on this pad and arms on the desk. I'd really appreciate it if you could **refrain from fidgeting** or moving your hands throughout the procedure – fidgeting doesn't help you beat the test, it just results in poor data

#### 5. CIT procedure

- I'll explain how the lie detection test is going to work. **We've taken 4 specific details** of the crime and used these to create 4 questions that we are certain that the guilty person will recognize the answer to. The questions and possible options will be presented on a computer / in VR twice. Any recognition of these items will be treated as guilt. [SHOW]
- For each question you simply have to **respond with "No"** when the option is presented.
- There will be a pause after each item and overall the test will take **10 minutes**.

#### 6. [IF VR CONDITION] Set up the Virtual Reality

- We'll now put on the **VR headset** here (show the participant the VR headset) which can be adjusted for your comfort using these straps.
- You can **remove the headset** at any point if you are feeling uncomfortable.
- You're unlikely to feel any **motion sickness** as you will be stationary in the virtual environments. However, if this does happen then please remove the headset and let me know. I have water here if that'll help.
- Try not to move your head too much and **feel free to hold the headset** if that's more comfortable.
- During the lie detection test please **do not close your eyes** as a method for trying to fool the test. In the real world we would use eye tracking within the headset to check for this but as this is an experiment, we ask that you do not try this obvious method.

#### 7. Preview

- I'll now show you a **preview of all the questions** and possible options that we are going to present to you in the main test just, so you can get familiar with the process

#### 8. Start CIT

#### 9. Memory Check and Debrief

*Figure A.34. Instructions for Caught Virtually Lying (pg 2/3)*

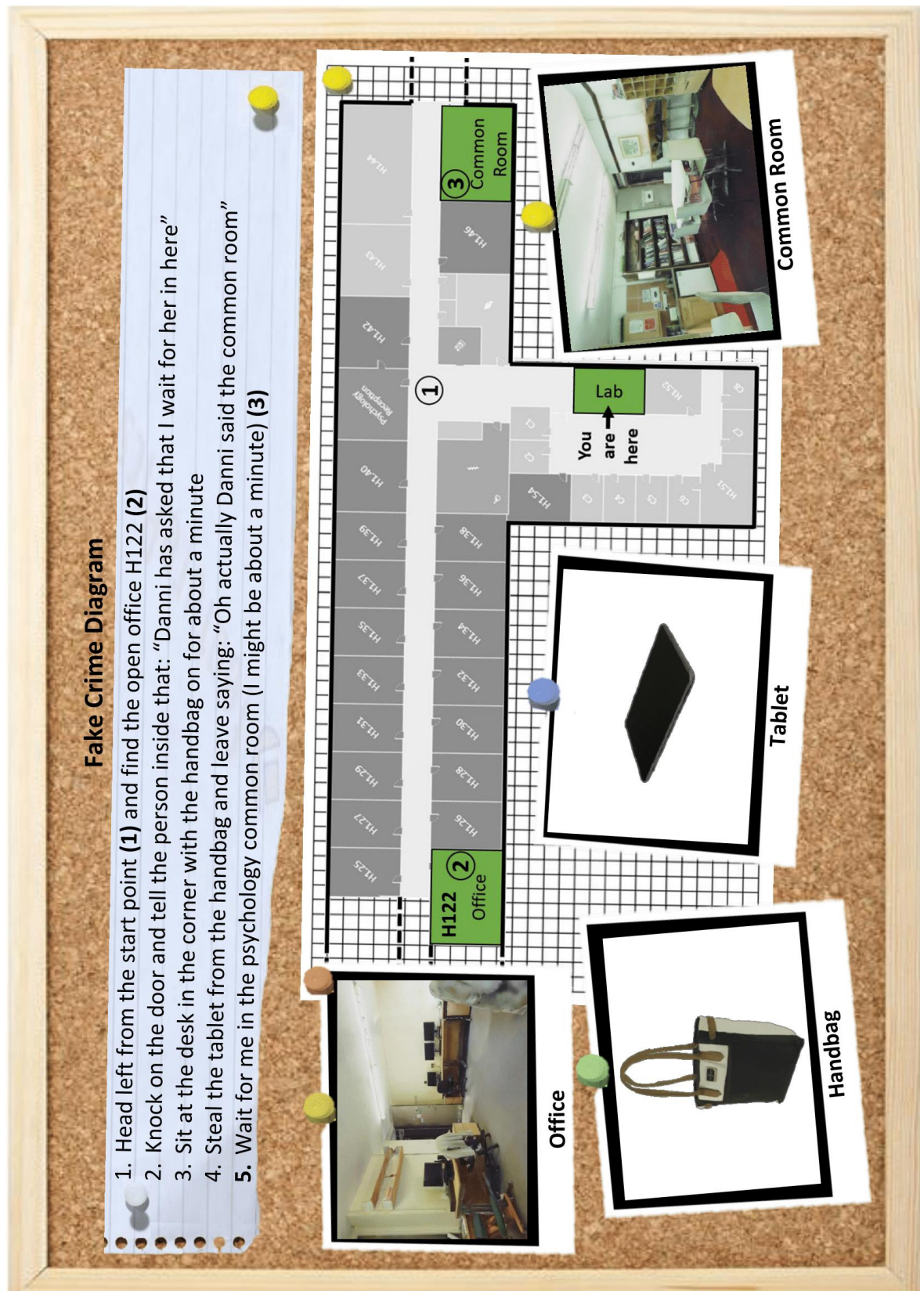


Figure A.35. Instructions for Caught Virtually Lying (pg 3/3)

### Latency Effects on Autonomic Measures in a Mock Crime Concealed Information Test

Danni Norman, Derrick Watson

#### For Consent

You are going to see some questions and images on a screen that you'll respond verbally to e.g. "I don't know".

Your skin conductance will be measured using two electrode pads which the experimenter will show you.

If you have any questions about the procedure then please ask.

#### [Experiment to connect pads]

#### [Sign Consent form]

#### [Participant Read Background]

#### Situation

Within the last few months someone stole a valuable item from a black bag on university campus. It appears that the culprit knew exactly where to find this black bag which was left next to another everyday object for only a short period of time. We believe this valuable item was then taken to another suspect somewhere on university campus.

We have been very careful not to let anyone else know about the exact items and places that relate to this crime and therefore knowledge of any of these crime items will be treated as guilt. Does this all make sense?

CCTV identified a number of potential suspects near the area where the crime took place and you were one of those people. We appreciate that this doesn't make you the culprit however to be sure we would like to administer a short polygraph test.

Obviously if you are guilty of the crime then you can admit this now.

1. Are you guilty of this crime?
2. So you don't know where the crime took place?
3. What about the type of black bag the valuable item was in?
4. How about the valuable item was stolen?
5. Or what object was left near the black bag?
6. And I guess then you don't know where the item was then taken to?

The questions you will be asked are similar to the ones I just asked and will be presented in a random order.

1. Was this the place where the item was stolen?
2. Was this the item that was stolen?
3. Was this the bag the item was stolen from?
4. Was this object next to the bag at the crime scene?
5. Was this the place where the item was taken back to?

We'll go through one question at a time. The image will appear for a few second with a few second gap between them.

As you claim you do not know the crime items as you are innocent, simply responds as soon as you've seen the image with "I don't know" or "I'm not sure"

The test takes around 6 minutes to complete.

#### [CIT Test]

**Memory Check** - The experiment has now ended. Please identify which items you remember from the crime.

#### Background

Within the last few months you took part in a study where you were asked to imagine yourself as having committed a crime. You were instructed to lie about committing that crime. This part of the study will try to detect if you are lying. Please now reimage yourself as the suspect who committed that crime and remember what you did (without telling the current investigator). Until the investigator says otherwise, please hide any knowledge of the 'crime' you committed and lie about anything that might make you look guilty. Any knowledge of the crime will be treated as guilty.

When you are ready please let the experimenter know that they can start the study.

*Figure A.36. Instructions for Fading Memories Experiment 1*

Department of Psychology: Experimenter Instructions  
 Examining the Effects of Rapid vs Gradual Stimulus Onset in the Concealed Information Test  
 Researchers: Milly Newman, Olugbemi Moronfolu, Derrick Watson & Danni Norman

## Experimenter Instruction Sheet

*(Give the participant a copy of this sheet to follow as the experimenter reads it out loud)*

### 1. Consent Form

Participant given an overview of the experiment procedure and invited to give consent to take part

### 2. Attached Electrodes

If you are comfortable the experimenter will now attach two pairs of electrodes to allow them to dry prior to part 2 of the study. One pair of electrodes attached to your 1<sup>st</sup> and 2<sup>nd</sup> finger on your non-dominant hand and will measure skin conductance with is essential a measure of sweat on a small scale. The other pair of electrodes attach to your dominant hand wrist and the opposite ankle and will measure heart rate. The experimenter will show you how these will be attached first on themselves and then invite you to either; attach them on yourself or allow the experimenter to attach them for you. If you do not wish for any particular electrodes to be attached, then this is fine and please say now.

### 3. Experiment Instructions Part 1

Your primary task in this study will be to play the role of a criminal during a lie detection test. You'll aim to appear as innocent as possible by lying about any information you will soon recognise from the crime video.

In this room, you can ask any questions relating to any part of the experiment however when you start part 2 of the experiment in the interview room next door, you'll be aiming to convincingly play the role of guilty suspect. The other experimenter next door will be playing the role of a criminal investigator and will conduct the lie detection test as if it's real!

### 4. Video Instructions

You'll now watch a three minute, 1<sup>st</sup> person perspective, mock crime video during which you are to imagine as best as possible that you are the person in the video carrying out the tasks.

**It's really important you pay attention throughout and really try and imagine yourself as the person whose perspective your seeing in the video. There will also be a memory test at the end.**

During the video you'll be left in this room alone with lights off and door shut. When the video has finish please press this switch on the table and the experimenter will return to provide further instruction. If there are any issues during the video the experimenter will just be outside. To stop the video just press SPACE but only if needed – the video should run uninterrupted.

The experimenter will now set up the video, provide you with the 3D glasses if appropriate and ask you to stand up against the table (You may find leaning on the table helpful if you are prone to motion sickness). When the experimenter has left then press start.

### 5. Watch Video

### 6. Post Video Instructions

Please now imagine you have been contacted by the local police station and have been informed that you are a potential suspect in a recent crime. They explain that during their investigation they would like to administer a lie detection test to all potential suspects to help narrow down their investigation. When you are ready you will be taken next door where to meet the investigator and take the lie detection test.

**Remember it's really important that you try and remain in role (the investigator will be) and DO NOT let the investigator know you are guilty– They will be trying to work this out!**

### 7. Experiment Part 2

Participant taken to the interview room to begin part 2 of the experiment

*Figure A.37. Instructions for Fading Memories Experiment 2 (pg 1/2)*

Department of Psychology: Investigator Instructions  
 Examining the Effects of Rapid vs Gradual Stimulus Onset in the Concealed Information Test  
 Researchers: Milly Newman, Olugbemi Moronfolu, Derrick Watson & Danni Norman

## Investigator Instruction Sheet

(Conversation style)

- ☐ Hello, I am the criminal investigator conducting this procedure today.
- ☐ Thank you for coming in and helping us out with our investigation.
- ☐ You might be wondering why we've invited you in today, so I'll explain the situation.

### So what is the crime we're investigating?

- ☐ Within the last few days someone stole a **valuable item** from a bag **somewhere** on Warwick University Campus.
- ☐ Although the bag was padlocked the thief managed to **disable** the lock and steal the item inside
- ☐ We have CCTV footage of the **place** where the item was stolen from but, unfortunately for us, the camera was **masked** by the thief.
- ☐ We know that the thief later met with an **accomplice** to exchange the stolen item for cash
- ☐ We know because a witness reported exactly **when** and **where** this exchange occurred
- ☐ We now have the accomplice in custody, so we know how much they **paid** for the stolen item.
- ☐ Do you know anything about this?

### So why are you here?

- ☐ Unfortunately, you, along with a few others, match the witness's description of the suspect.
- ☐ To narrow down our investigation, we are administering a lie detection test to all suspects
- ☐ Firstly, we'd like to offer you the opportunity to confess –were you the thief in this crime?
- ☐ OK so as you are claiming innocence I'm sure you won't mind taking the lie detector test?

### I'll now describe how the procedure will work

- ☐ We've been very careful to keep the specific details of the crime secret and have used these details to create 8 questions which we are certain only the guilty suspect will recognize the answer  
     [Participant to be shown each multiple-choice question with each containing one crime item. Clarify that each question has 5 possible options presented sequentially]
- ☐ As you can see each question is phrased as, **Do you recognise** this particular item as the one etc, you only need to respond verbally with **No**. Please respond clearly for the webcam mic
- ☐ Any questions so far?

### OK so we'll now attach the electrodes

- ☐ Please keep your palm faced down on this pad and sit close to the wall with arms on the desk.
- ☐ I'd really appreciate it if you could refrain from fidgeting or moving your hands throughout the procedure – fidgeting won't help you beat the test, it just results in poor data
- ☐ There will be a pause after each item is presented and overall the test will take 15 minutes.
- ☐ Once the test has **finished** or if you need any **assistance** then press this **button** [indicate bell]
- ☐ Are you ready to proceed? [Start Procedure]

Figure A.38. Instructions for Fading Memories Experiment 2 (pg 2/2)



## Experiment Procedure

### Introduction ≈ 5mins

- Overview of Experiment Procedure followed by consent form

### Stimuli ≈ 20mins

- Randomly assigned to the crime or non-crime condition (the experiment is unaware of which you will be)
- Watch a 1<sup>st</sup> person video you'll imagine you are the character who will complete either a crime or non-crime task
- Either "email" from:  
Your accompish (Crime condition only) **OR** The criminal investigator (Non-Crime condition only) along with your alibi statement, alibi evidence and the lie detection test images
- Memorise these as there will be a memory test at the end which will contribute to your overall score

### Lie Test Stage ≈ 35mins

- Assume your character
- 3 tests including a practice test.

#### Practice Test = 2mins

- An introduction to the equipment that'll be used to measure your physiological changes during the tests.
- A practice test consisting of 1 block of 6 images, two of which you will be familiar with as they are scenes of Warwick University.
  - A question will be displayed and the each image will be displayed for 5s with a 5s gap between them. You need to lie and respond "no" to all scenes of Warwick University but "Yes" to Warwick University Library. Respond "no" to all other scenes that you do not recognise.

#### Test 1 = 9mins

- Same as above but with 5 Warwick Scenes. Gap between each image will now be 10s

#### Test 2 = 13mins

- Same as above however now the images will be the 8 items of evidence from your alibi and the crime
  - You need to respond "yes" to the items you provided in your alibi and "no" or "don't know" to anything else.

#### Test 3 = 10mins

- Reaction time test containing a selection of images from your alibi and the crime. You will have <1s to respond as quickly as possible to the images by pressing "yes" (LEFT KEY) or "no" (RIGHT KEY). With ≈1 second gap between each image, the test is fast. 90 images will be presented followed by a 10s break and then repeated 3x.

Note that the lie detection part of the experiment will finish here so you can break character

### Post Lie Test Stage ≈ 10mins

- Memory Test and Questionnaire ≈ 5mins
- Debrief and payment ≈ 2mins

**Total Duration ≈ 1.25hrs**

*Figure A.39. Instructions for Unobtrusive Measures study*

## Stimuli

Stimuli (Probe left)

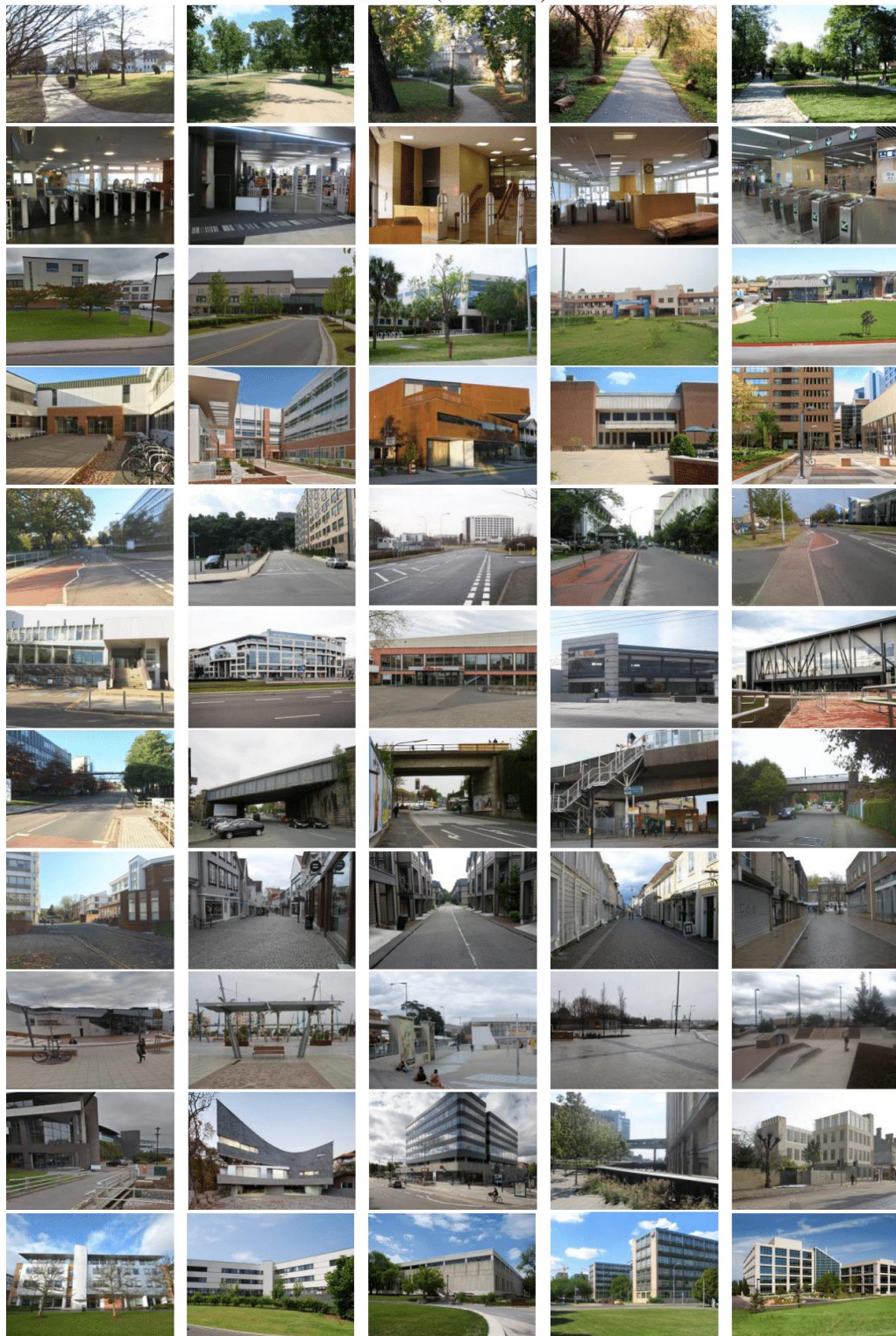


Figure A.40. Retrieval stimuli for *Seen this Scene*, Experiment 1 (pg 1/2)



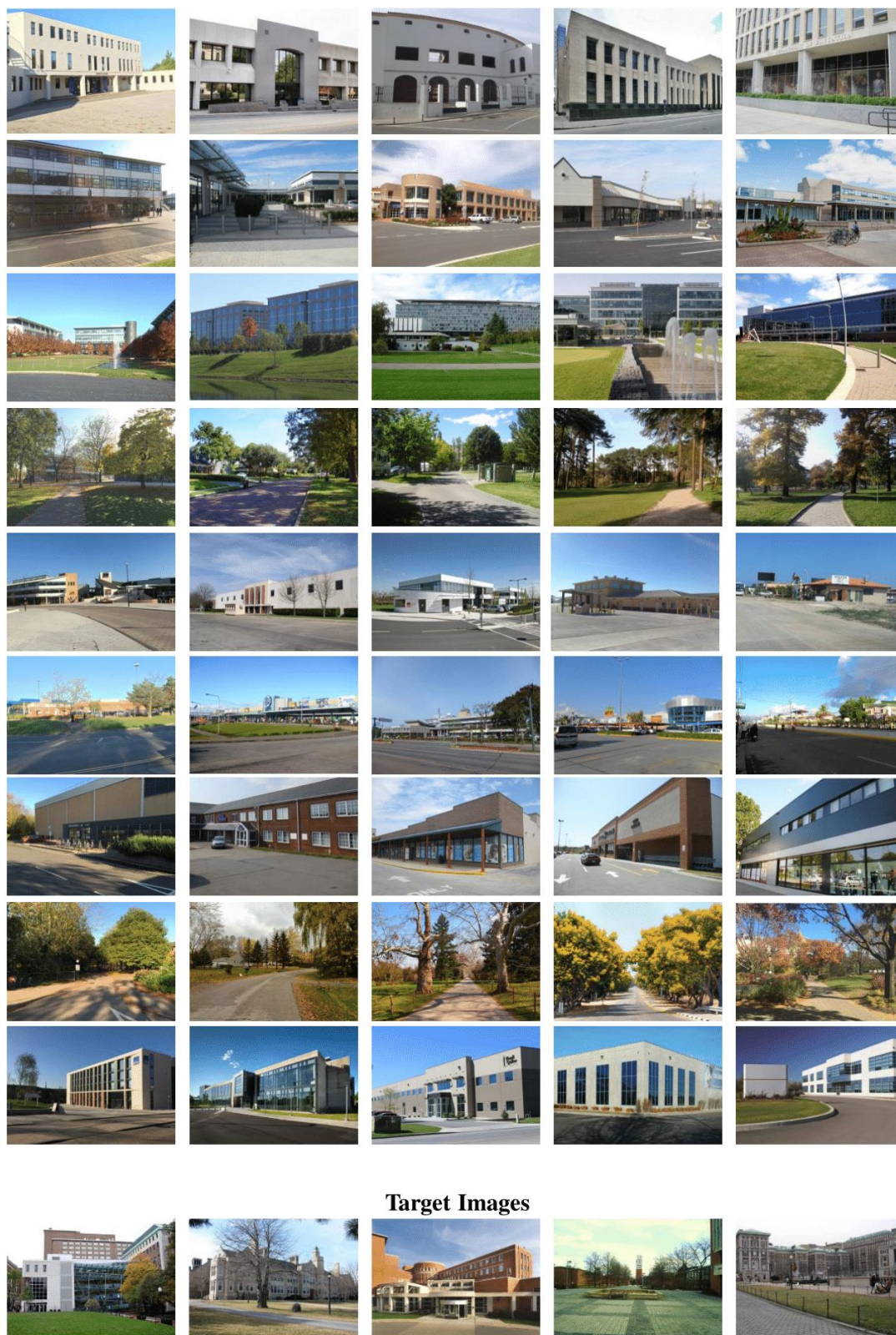


Figure A.41. Retrieval stimuli for *Seen this Scene, Experiment 1* (pg 2/2)



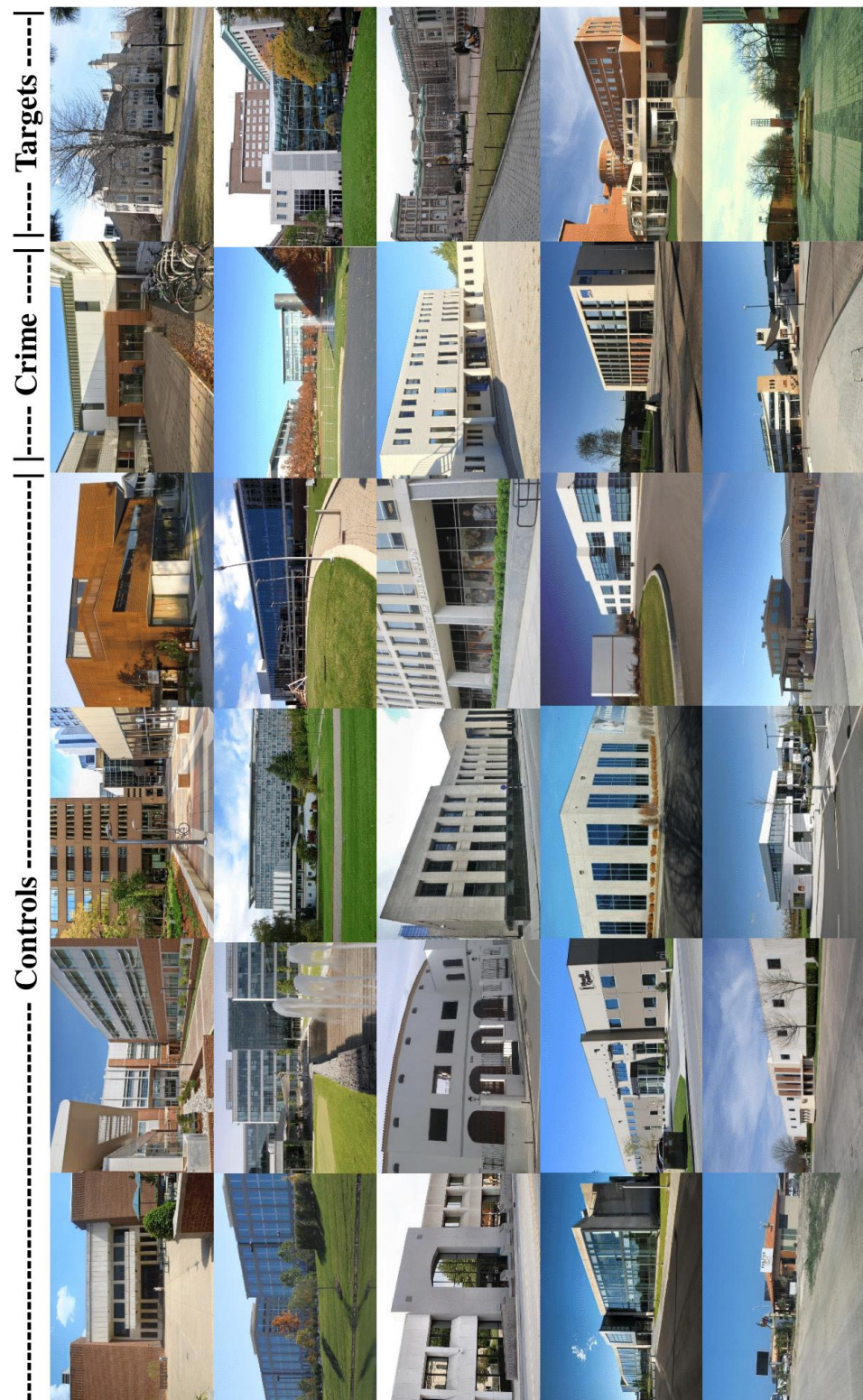


Figure A.42. Retrieval stimuli for *Seen this Scene, Experiment 3* and *Partners in Crime, Experiment 4*

### CIT Questions

1. The CCTV camera in the lab was masked. Do you recognize any of the following as the **method** used to cover the CCTV camera? <sup>(1)</sup>

a) Blu Tack



b) Shaving Foam



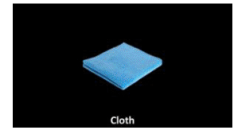
c) Duct Tape



d) Spray Paint



e) Cloth

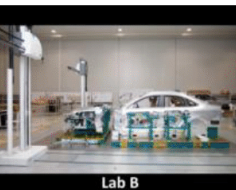


2. Few have access to the highly secret lab that was broken into. Do you recognize any of the following as the **lab** that was broken into? <sup>(3)</sup>

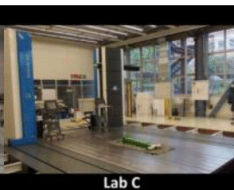
a) Lab A



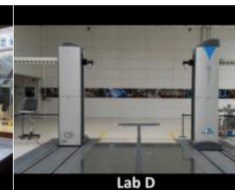
b) Lab B



c) Lab C



d) Lab D

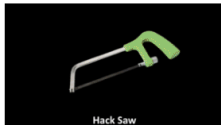


e) Lab E



3. The hologram device was inside a padlocked case. Do you recognize any of the following as the **tool** used to disable this lock? <sup>(1)</sup>

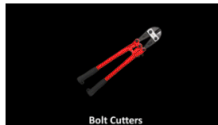
a) Hack Saw



b) Wire Cutters



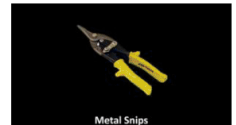
c) Bolt Cutters



d) Lock Picks



e) Metal Snips

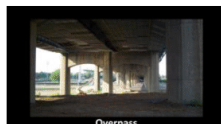


4. The stolen items were handed over at a predetermined location. Do you recognize any of the following as the **location** as where the handover took place? <sup>(1)</sup>

a) Town Centre



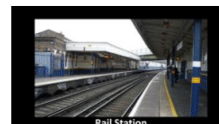
b) Overpass



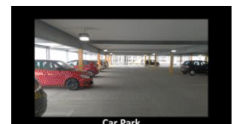
c) Park



d) Rail Station

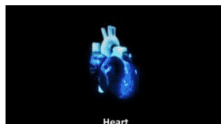


e) Car Park

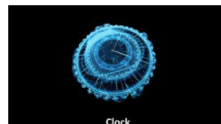


5. The hacked computer required a secondary image password. Do you recognize any of the following as the **image** password? <sup>(2)</sup>

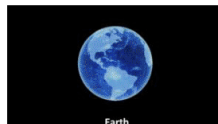
a) Heart



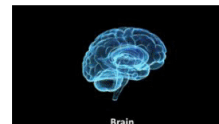
b) Clock



c) Earth



d) Brain



e) JellyFish



Figure A.43. Retrieval stimuli for Partners in Crime, Experiment 1-3 & 6 (pg 1/2)

6. We have the accomplice who organised the theft and received the device in custody. Do you recognize any of the following as the **accomplice** in this crime? <sup>(3)</sup>

a) Chris

b) James

c) Tom

d) Mike

e) Steve



7. The review room next to the office displayed information about the device. Do you recognize any of the following as the **information** on the screen? <sup>(2)</sup>

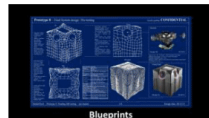
a) Financial Details

b) Blueprints

c) Facility Locations

d) Bespoke Software

e) Future Patents



8. The office on the first floor was accessed using a keycard. Do you recognize any of the following as the specific **office** accessed? <sup>(2)</sup>

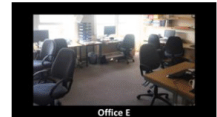
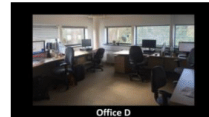
a) Office A

b) Office B

c) Office C

d) Office D

e) Office E



9. The door to the lab was forced open. Do you recognize any of the following as the **device** used to force the door? <sup>(3)</sup>

a) Sledgehammer

b) Hydraulic Ram

c) Crowbar

d) Lock Drill

e) Door Ram



Figure A.44. Retrieval stimuli for Partners in Crime, Experiment 1-3 & 6 (pg 2/2)



Department of Psychology: Questions and Items  
 Virtual Reality Lie Detection using the Physiological Concealed Information Test  
 Researchers: Danni Norman & Derrick Watson

### CIT Questions

**1. If you are guilty, you will recognise where the stolen item was handed over. Was this the place?...**

a) Stairwell



b) Photocopier Room



c) Common Room



d) Outside Lift



**2. If you are guilty, you will recognise what bag the stolen item was in. Was this the bag?...**

a) Satchel



b) Rucksack



c) Sports Bag



d) Handbag



**3. If you are guilty, you will recognise what the stolen item was. Was this the item?...**

a) Laptop



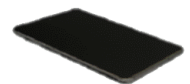
b) Purse



c) Headphones



d) Tablet

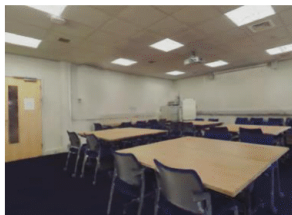


**4. If you are guilty, you will recognise where the item was stolen from. Was it stolen from here?...**

a) Office



b) Seminar Room



c) Lecture theatre



d) Computer Lab



*Figure A.45 Retrieval stimuli for Caught Virtually Lying*

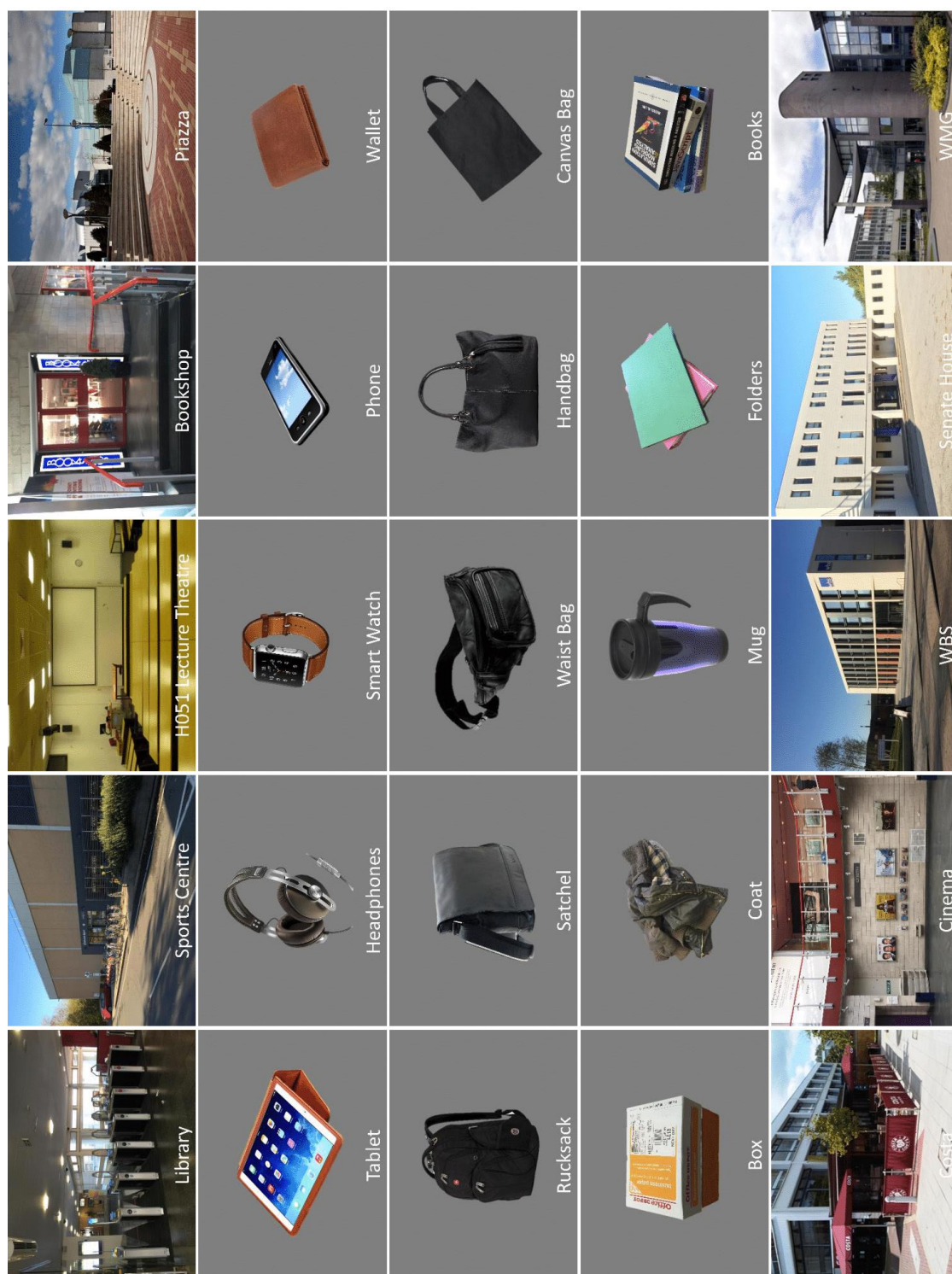


Figure A.46. Retrieval stimuli for *Fading Memories*, Experiment 1

## The Polygrapher's Problem - Investigator Effects in the Physiological Concealed Information Test

Researchers: Danni Norman &amp; Kimberley Wade

1. The item was sold to an accomplice somewhere on Warwick University Campus. Assuming you are guilty... do you recognize any of the following **Locations** as where you met your accomplice?

a) Outside WBS



b) SU Piazza



c) Rootes Sculpture



d) Car Park



e) Library Cafe



2. You may remember that we have the accomplice in custody. Assuming you are guilty... do you recognize any of the following **People** as your accomplice?

a) Chris



b) James



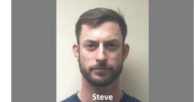
c) Tom



d) Mike



e) Steve



3. The stolen item was removed from a padlocked bag. Assuming you are guilty... do you recognize any of the following **Tools** that you used to disable the lock?

a) Hack Saw



b) Lock Picks



c) Wire Cutters



d) Metal Snips



e) Bolt cutters



4. If you recall the CCTV camera at the crime scene was masked. Assuming you are guilty... do you recognize any of the following **Methods** you used to cover the CCTV camera?

a) Blu Tack



b) Shaving Foam



c) Duct Tape



d) Spray Paint



e) Post it Note



5. A witness provided us with the time that the suspects met to hand over the item. Assuming you are guilty... do you recognize any of the following **Times** that you met the accomplice?

a) 12:00



b) 16:00



c) 18:00



d) 23:00



e) 22:00



6. The accomplice informed us of how much they paid for the stolen item. Assuming you are guilty... do you recognize any of these cash **Amounts** as the amount paid for the item?

a) £80



b) £100



c) £90



d) £70



e) £60



7. The victim reported which item was stolen from the bag. Assuming you are guilty... do you recognize any of the following as the **Stolen Item**?

a) Laptop



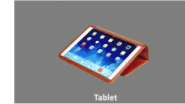
b) Smart Watch



c) Headphones



d) Tablet



e) Phone

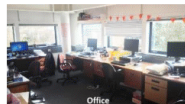


8. The item was stolen from somewhere on Warwick University Campus. Assuming you are guilty, do you recognize any of the following **Places** as the site where the item was stolen from?

a) Costa



b) Office



c) Lecture Theatre



d) Library



e) Learning Grid



Figure A.47. Retrieval stimuli for *What do you know*, Experiment 1-2 and *Fading*

*Memories*, Experiment 2



## Department of Psychology: Questions and Items

## Reaction Time Deception Detection Task with Mock Crime Stimuli

Researchers: Danni Norman &amp; Derrick Watson

1. Do you recognise any of the following **Locations** as where you met the accomplice?

a) Outside WBS

b) SU Piazza

c) Rootes Sculpture

d) Car Park

e) Library Cafe

2. Do you recognise any of the following **Places** as where the bike was stolen from?

a) Engineering

b) Humanities

c) Law School

d) Sports Centre

e) Library

3. Do you recognise any of the following **Tools** as the one used to break the lock?

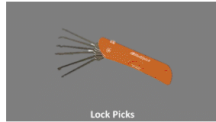
a) Hack Saw

b) Lock Picks

c) Wire Cutters

d) Metal Snips

e) Bolt cutters

4. Do you recognise this as the **Method** used to cover the CCTV camera?

a) Blu Tack

b) Shaving Foam

c) Duct Tape

d) Spray Paint

e) Post it Note

5. Do you recognise any of the following **People** as suspect B?

a) Chris

b) James

c) Tom

d) Mike

e) Steve

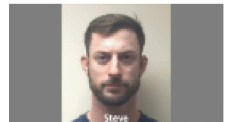
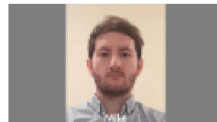


Figure A.48. Retrieval stimuli for Upstanding or underhand, Experiment 5 and Seen this Scene, Experiment 2 – Stimuli (first four)

## Post CIT Questionnaire

P No:

Department of Psychology: Memory Check and Feedback

### Reaction Time Deception Detection Task with Mock Crime Stimuli

Researchers: Danni Norman & Derrick Watson

#### Post Test Memory Check

This task serves as a memory check for each crime item presented. It is important that you don't try and guess the correct answer – if you don't remember then please circle f) Can't Remember for that question. Some of items can be difficult to remember. Also as the lie detection part of the study is over please answer this memory check truthfully.

1. Do you recognise any of the following **Locations** as where you met the accomplice?

a) Outside WBS   b) SU Piazza   c) Rootes Sculpture   d) Car Park   e) Library Café   f) Can't Remember

2. Do you recognise any of the following **Places** as where the bike was stolen from?

a) Engineering   b) Humanities   c) Law School   d) Sports Centre   e) Library   f) Can't Remember

3. Do you recognise any of the following **Tools** as the one used to break the lock?

a) Hack Saw   b) Lock Picks   c) Wire Cutters   d) Metal Snips   e) Bolt cutters   f) Can't Remember

4. Do you recognise this as the **Method** used to cover the CCTV camera?

a) Blu Tack   b) Shaving Foam   c) Duct Tape   d) Spray Paint   e) Post it Note   f) Can't Remember

5. Do you recognise any of the following **People** as suspect B?

a) Chris   b) James   c) Tom   d) Mike   e) Steve   f) Can't Remember

#### Post Interview Task 2

Please rate your motivation during the study?

Not motivated   1   2   3   4   5   6   Highly Motivated

How immersive did you find the stimuli video?

Not immersive   1   2   3   4   5   6   Highly immersive

i.e. couldn't imagine myself  
as the character in the video

i.e. easy to imagine I was  
really carrying out those tasks

Please bullet point any countermeasures / methods you used to fool the test e.g. trying to ignore images etc. If you didn't attempt any countermeasure this is also fine.

How well did you think you did at appearing innocent during the lie detection part?

Not very well   1   2   3   4   5   6   Very well

i.e. probably identified  
as the culprit

i.e. would have been classified as having  
no knowledge of the crime / innocent

Any other comments or feedback welcome below

*Figure A.49. Post CIT Questionnaire for Upstanding or underhand, Experiment 5 and Seen this Scene, Experiment 2 – Stimuli (first four)*



P No: 

Department of Psychology: Memory Check and Feedback  
Partners in Crime - Shared Information and Paired Testing in the Concealed Information Test  
Researchers: Danni Norman & Derrick Watson

## Memory and Feedback Sheet

### Post Interview Task 1

The lie detection part of this study is over. This task serves as a memory check for each crime item presented. Please don't try to guess the correct answer – if you don't remember then circle f) Can't Remember - some items are difficult to remember.

1. The CCTV camera in the lab was masked. Do you recognize any of the following as the **method** used to cover the CCTV camera? <sup>(1)</sup>

a) Blu Tack                      b) Shaving Foam   c) Duct Tape                      d) Spray Paint                      e) Cloth                      f) Can't remember

2. Few have access to the highly secret lab that was broken into. Do you recognize any of the following as the **lab** that was broken into? <sup>(3)</sup>

a) Lab A                      b) Lab B                      c) Lab C                      d) Lab D                      e) Lab E                      f) Can't remember

3. The hologram device was inside a padlocked case. Do you recognize any of the following as the **tool** used to disable this lock? <sup>(1)</sup>

a) Hack Saw                      b) Wire Cutters                      c) Bolt Cutters                      d) Lock Picks                      e) Metal Snips                      f) Can't remember

4. The stolen items were handed over at a predetermined location. Do you recognize any of the following as the **location** as where the handover took place? <sup>(1)</sup>

a) Town Centre                      b) Overpass                      c) Park                      d) Rail Station                      e) Car Park                      f) Can't remember

5. The hacked computer required a secondary image password. Do you recognize any of the following as the **image** password? <sup>(2)</sup>

a) Heart                      b) Clock                      c) Earth                      d) Brain                      e) JellyFish                      f) Can't remember

6. We have the accomplice who organised the theft and received the device in custody. Do you recognize any of the following as the **accomplice** in this crime? <sup>(3)</sup>

a) Chris                      b) James                      c) Tom                      d) Mike                      e) Steve                      f) Can't remember

7. The review room next to the office displayed information about the device. Do you recognize any of the following as the **information** on the screen? <sup>(2)</sup>

a) Financial Details                      b) Blueprints                      c) Facility Locations                      d) Bespoke Software                      e) Future Patents                      f) Can't remember

8. The office on the first floor was accessed using a keycard. Do you recognize any of the following as the specific **office** accessed? <sup>(2)</sup>

a) Office A                      b) Office B                      c) Office C                      d) Office D                      e) Office E                      f) Can't remember

9. The door to the lab was forced open. Do you recognize any of the following as the **device** used to force the door? <sup>(3)</sup>

a) Sledgehammer                      b) Hydraulic Ram                      c) Crowbar                      d) Lock Drill                      e) Door Ram                      f) Can't remember

*Figure A.50. Post CIT Questionnaire for Partners in Crime, Experiment 1-3 & 6*

*(pg 1/2)*

-----

### Post Interview Task 2

Please rate your general motivation during the study?

Not motivated      1      2      3      4      5      6      Highly Motivated

Please rate how stressed you felt during the lie detection stage?

No stress      1      2      3      4      5      6      Very Stressed

How immersive did you find the stimuli video?

Not immersive      1      2      3      4      5      6      Highly immersive  
i.e. couldn't imagine myself as      i.e. easy to imagine I was  
the character in the video      really carrying out those tasks

Did you do anything to try and fool the test? If you did or didn't please bullet point below – either case is fine.

How well did you think you did at appearing innocent during the lie detection test?

Not very well      1      2      3      4      5      6      Very well  
i.e. probably identified      i.e. would have been  
as the culprit      classified as innocent

Any other comments or feedback:

e.g. how was the video? ect

*Figure A.51. Post CIT Questionnaire for Partners in Crime, Experiment 1-3 &6 (pg 2/2)*

Department of Psychology: Memory Check and Feedback

**The Polygrapher's Problem - Investigator Effects in the Physiological Concealed Information Test**

Researchers: Danni Norman &amp; Kimberley Wade

**Post Interview Task 1**

This task serves two purposes. For guilty suspect participant, it acts as a memory check for each crime item presented. It is important that you don't try and guess the correct answer – if you don't remember then please circle f) Can't Remember for that question. Some of items can be difficult to remember. As the lie detection part of the study is over please answer this memory check truthfully. For participants playing innocent suspects, please indicated what you may have guessed was the correct crime item for each question. This helps us identify if there are any items that stick out to unknowledgeable suspects.

1. The item was sold to an accomplice somewhere on Warwick University Campus. Do you recognize any of the following **Locations** as where you met your accomplice?

- a) Outside WBS   b) SU Piazza   c) Rootes Sculpture   d) Car Park   e) Library Café   f) Can't Remember

2. You may remember that we have the accomplice in custody. Do you recognize any of the following **People** as your accomplice?

- a) Chris   b) James   c) Tom   d) Mike   e) Steve   f) Can't Remember

3. The stolen item was removed from a padlocked bag. Do you recognize any of the following **Tools** that you used to disable the lock?

- a) Hack Saw   b) Lock Picks   c) Wire Cutters   d) Metal Snips   e) Bolt cutters   f) Can't Remember

4. If you recall the CCTV camera at the crime scene was masked. Do you recognize any of the following **Methods** you used to cover the CCTV camera?

- a) Blu Tack   b) Shaving Foam   c) Duct Tape   d) Spray Paint   e) Post it Note   f) Can't Remember

5. A witness provided us with the time that the suspects met to hand over the item. Do you recognize any of the following **Times** that you met the accomplice?

- a) 12:00   b) 16:00   c) 18:00   d) 23:00   e) 22:00   f) Can't Remember

6. The accomplice informed us of how much they paid for the stolen item. Do you recognize any of these cash **Amounts** as the amount paid for the item?

- a) £80   b) £100   c) £90   d) £70   e) £60   f) Can't Remember

7. The victim reported which item was stolen from the bag. Do you recognize any of the following as the **Stolen Item**?

- a) Laptop   b) Smart Watch   c) Headphones   d) Tablet   e) Phone   f) Can't Remember

8. The item was stolen from somewhere on Warwick University Campus. Do you recognize any of the following **Places** as the site where the item was stolen from?

- a) Costa   b) Office   c) Lecture Theatre   d) Library   e) Learning Grid   f) Can't Remember

**Post Interview Task 2**

Please rate your motivation during the study?

Not motivated   1   2   3   4   5   6   Highly Motivated

Please rate how stressed you felt during the lie detection stage?

No stress   1   2   3   4   5   6   Very Stressed

How immersive did you find the stimuli video?

Not immersive   1   2   3   4   5   6   Highly immersive  
i.e. couldn't imagine myself as the character in the video   i.e. easy to imagine I was really carrying out those tasks

Did you do anything to try and fool the polygraph test? If you did or didn't please bullet point below – either case is fine.

How well did you think you did at appearing innocent during the lie detection test?

Not very well   1   2   3   4   5   6   Very well  
i.e. probably identified as the culprit   i.e. would have been classified as having no knowledge of the crime / innocent

Any other comments or feedback:

*Figure A.52. Post CIT Questionnaire What do you know, Experiment 1-2 and similar to Fading Memories, Experiment 1*

Department of Psychology: Memory Check and Feedback  
**Virtual Reality Lie Detection using the Physiological Concealed Information Test**  
 Researchers: Danni Norman & Derrick Watson

P No:

### Memory and Feedback Sheet

The lie detection part of this study is over. If you were 'guilty', this task serves as a memory check for each crime item presented. If 'guilty', please don't try to guess the correct answer – if you don't remember then circle **e) can't remember**.

If you were 'innocent' then pick the items you thought might have been the crime items.

1. If you are guilty, you will recognise where the stolen item was handed over. Do you recognise this:

- a) Stairwell                      b) Photocopier Room                      c) Common Room                      d) Outside Lift                      e) Can't remember

2. If you are guilty, you will recognise what bag the stolen item was in. Do you recognise this:

- a) Satchel                      b) Rucksack                      c) Sports Bag                      d) Handbag                      e) Can't remember

3. If you are guilty, you will recognise what the stolen item was. Do you recognise this:

- a) Laptop                      b) Purse                      c) Headphones                      d) Tablet                      e) Can't remember

4. If you are guilty, you will recognise where the item was stolen from. Do you recognise this:

- a) Office                      b) Seminar Room                      c) Lecture theatre                      d) Computer Lab                      e) Can't remember

-----  
 Please rate your general motivation during the study?

Not motivated                      1                      2                      3                      4                      5                      6                      Highly Motivated

If relevant, please rate how stressed you felt during the fake crime stage?

No stress                      1                      2                      3                      4                      5                      6                      Very Stressed

Please rate how stressed you felt during the lie detection stage?

No stress                      1                      2                      3                      4                      5                      6                      Very Stressed

Did you do anything to try and fool the test? If you did or didn't please bullet point below – either case is fine.

How well did you think you did at appearing innocent during the lie detection test?

Not very well                      1                      2                      3                      4                      5                      6                      Very well  
 i.e. probably identified                      i.e. would have been  
 as the culprit                      classified as innocent

Any other comments or feedback: e.g. what would you do to improve the test or if relevant the virtual reality?

*Figure A.53. Post CIT Questionnaire Caught Virtually Lying*

Participant No.

## Memory Check and Questionnaire

Please note that the lie detection part of the experiment is now finished so please answer truthfully (if you have been in the lie condition). This is so your memory for the items can be checked.

**Q1.** Look at the questions below (some of them you saw in the tests). Circle the correct Alibi image in green and the crime image\* in red for each question.

\*If you **didn't** commit the crime then try and guess which items could have been in the crime video

1. Was this the physical item that you acquired?



2. Was this the digital information that you acquired?



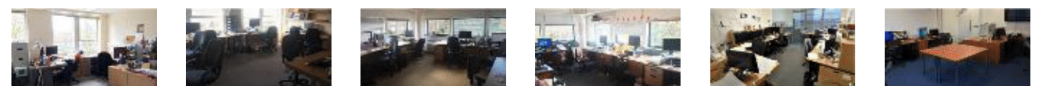
3. Was this the item used to acquire the secured item?



4. Was this the lab where the item was located?



5. Was this the office where the computer data was accessed?



6. Is this the password that was used to access the PC?

vTREE/2007&amp;

JESS.030409

ySEAS.2015\*

iSTAR.2017#

zSUNS-2016?

xMOON,2018\$

7. A security image followed the PC password, was this the image?



Figure A.54. Post CIT Questionnaire Unobtrusive Measures Study (pg 1/3)
























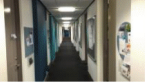












| Participant No.   |   |   |  |   |   |
|---|---|---|--|---|---|
| 8. Is this the person you were acquiring the items for?                                   |   |   |  |   |   |
|          |    |    |    |    |    |
| 9. Was this the method used to download the data from the secure PC?                      |   |   |  |   |   |
|          |    |    |    |    |    |
| 10. How was the item carried out of the building?   |   |   |  |   |   |
|          |    |    |    |    |    |
| 11. Is this where the item will be going?   |   |   |  |   |   |
| PARIS,<br>FRANCE  | ROME,<br>ITALY  | BEIJING,<br>CHINA   | MOSCOW,<br>RUSSIA  | MADRID,<br>SPAIN  | BERLIN,<br>GERMANY  |
| 12. Is this the amount the buyer will pay for the item? (does not require a green circle) |   |   |  |   |   |
| £300,000  | £1,000,000  | £800,000  | £100,000   | £1,500,000  | £500,000  |
| 13. Is this a corridor in the building where the item was located?                        |   |   |  |   |   |
|        |  |  |  |  |  |
| 14. Do you recognise this part of the building?   |   |   |  |   |   |
|        |  |  |  |  |  |
| 15. Is this where you dropped off the items to your partner?                              |   |   |  |   |   |
|        |  |  |  |  |  |

Figure A.55. Post CIT Questionnaire Unobtrusive Measures Study (pg 2/3)

Figure A.56. Post CIT Questionnaire Unobtrusive Measures Study (pg 3/3)



## Debrief

Department of Psychology: Debrief Form  
Reaction Time Deception Detection Task  
Researchers: Danni Norman & Derrick Watson

P No:

### Background

You have just taken part in a reaction time deception detection test known as the Reaction Time Concealed Information Test (aka RTCIT). Although not designed to measure lying per se, this procedure aims to detect response inhibition to crime related items (e.g. images you are pretending not to recognise). The reaction time responses to the crime related items are compared against other items that don't relate to the crime.

### Present Study

In our research, we are interested in how different factors can affect detection of guilty suspects in the concealed information test. Research has shown that presenting threaten objects on the top of the screen can increase response time. This study was particularly interested in whether showing images on the top or bottom of the screen interacts with response times on the crime items and thereby create a more reliable lie detection test.

### Further information

Thank you for taking part and we hope you found the experiment interesting and educational. If you have any future questions then please feel free to email the experimenters. Alternatively you can reference the text below which provides a thorough review of the literature: *Verschuere, B., Ben-Shakhar, G., & Meijer, E. (Eds.). (2011). Memory detection: Theory and application of the Concealed Information Test. Cambridge University Press.*

For any further questions please email Danni Norman @ [REDACTED]

Thank you

### PLEASE NOTE

Please refrain from discussing the project with fellow participants as it might affect our results.

#### Complaints

Any complaint about the way you have been dealt with during the study or any possible harm you might have suffered will be addressed. Please address your complaint to the person below, who is a senior University of Warwick official entirely independent of this study:

Head of Research Governance  
Research & Impact Services  
University House  
University of Warwick  
Coventry CV4 8UW

*Figure A.57. Debrief sheet for Upstanding or underhand, Experiment 1-5 and similar to Seen this Scene, Experiment 2-3 and Partners in Crime, Experiment 4*



P.No

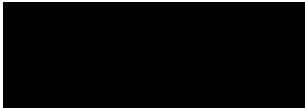
Department of Psychology: Debrief Sheet  
Partners in Crime - Shared Information and Paired Testing in the Concealed Information Test  
Researchers: Danni Norman & Derrick Watson

The study you participated in aimed to explore the accuracy of the Concealed Information Test.

The Concealed Information Test involves measuring one's orienting response (OR). By definition, an orienting response is a reflex, which brings about physiological responses to changes in the environment. The physiological responses we measured was EDA (skin conductance). Earlier research has shown that the OR of a guilty individual elicits an increase in skin conductance.

In the present study we attempt to determine: a) how accurate the CIT is in identifying guilty suspects when they are taking the test with an accomplice and b) whether individual suspects with shared knowledge show different CIT response to crime items compared to items that they do not have shared knowledge for. This is interesting as a tool for deception detection in groups of suspects with joint knowledge about a crime.

If you have any further questions, please contact one of the experimenters via the email address below:



**PLEASE NOTE**

Please refrain from discussing the project with fellow participants as it might affect our results.

**Complaints**

Any complaint about the way you have been dealt with during the study or any possible harm you might have suffered will be addressed. Please address your complaint to the person below, who is a senior University of Warwick official entirely independent of this study:

Head of Research Governance  
Research & Impact Services  
University House  
University of Warwick  
Coventry CV4 8UW  
Tel: 024 76 522746  
Email: [researchgovernance@warwick.ac.uk](mailto:researchgovernance@warwick.ac.uk)

*Figure A.58. Debrief sheet for Partners in Crime, Experiments 1-3 & 6*

P.No

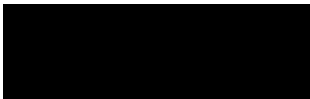
Department of Psychology: Debrief Sheet  
Virtual Reality Lie Detection using the Physiological Concealed Information Test  
Researchers: Danni Norman & Derrick Watson

The study you participated in aimed to explore the accuracy of the Concealed Information Test when it is administered in either Virtual Reality or using a computer monitor.

The Concealed Information Test (CIT) is a memory recognition test used as a deception detection tool sometimes used by law enforcement. Theoretically grounded, the CIT is a well-established paradigm in which participants see stimuli presented on a computer whilst their physiological responses are recorded. In the lab these stimuli are usually items relating to a fake crime which was carried out by the participant beforehand. The most commonly used mock crime procedure sees the participant locate and 'steal' an item from an office and then return to the item to the experimenter.

Previous work has demonstrated the importance of CIT item salience and presentation in this test. Presentation of CIT items in 3D using a Virtual Reality headset (as opposed to on a computer monitor) would likely increase both the item salience and recognition response of in the CIT – however this has yet to be tested. This study aims to test whether the CIT effect changes if items are presented in Virtual Reality compared to on a computer screen. This study will have both theoretical and applied impact.

If you have any further questions, please contact one of the experimenters via the email address below:



#### PLEASE NOTE

Please refrain from discussing the project with fellow participants as it might affect our results.

#### Complaints

Any complaint about the way you have been dealt with during the study or any possible harm you might have suffered will be addressed. Please address your complaint to the person below, who is a senior University of Warwick official entirely independent of this study:

Head of Research Governance  
Research & Impact Services  
University House  
University of Warwick  
Coventry CV4 8UW  
Tel: 024 76 522746  
Email: researchgovernance@warwick.ac.uk

*Figure A.59. Debrief sheet for Caught Virtually Lying*

P.No, Guilt, Condition

Department of Psychology: Debrief Form

**The Polygrapher's Problem - Investigator Effects in the Physiological Concealed Information Test**

Researchers: Danni Norman &amp; Kimberley Wade

**Background**

You have just taken part in a psychophysiological deception detection test known as the Concealed Information Test (aka Guilty Knowledge Test). Although not designed to measure lying per se, this procedure aims to detect recognition of crime related items that only a guilty suspect should recognize (e.g. the stolen item). The physiological responses (i.e. EDA) to the crime related items are compared against other items that don't relate to the crime. The test has been extensively validated and is used in real criminal investigations in Japan.

**Present Study**

In our research, we are interested in how the presentation of questions and items can affect detection of innocent and guilty suspects. This study was particularly interested in whether there is a meaningful difference when presenting questions and items manually with an investigator, compared to presenting them automatically using a PC. Research has suggested that a knowledgeable investigator who know the correct crime items may influence an innocent suspects physiological responses to those items, which could then result in an innocent suspect being misclassified as guilty.

**Part 1 - Video**

*Guilty Suspects:* It is logistically difficult to get participants to carry out a mock crime in person. Consequently, researchers often ask participants to remember written scenarios, storyboards or videos mock crimes. This test, sometimes referred to as a Memory Detection test, assumes that the suspect remembers the correct crime items and therefore attention to these items during the crime is crucial. To ensure participants in our study remembered the crime items we use a first-person mock crime video containing snapshots of each crime item as the video progressed to aid participant imagination, attention and therefore memory of the event. If you would like to see the video used for the innocent condition, then please ask the experimenter at the end.

*Innocent Suspects:* In most studies of this nature, innocent participants are not the focus group and are typically required primarily for control data. However, in our study, innocent suspects were the primary focus for our research question. Innocent suspects carried out the same tasks as the guilty suspects with the only difference being the videos they saw. Some participants can feel like the innocent suspect condition is 'less interesting' as they do not see the mock crime video or must lie during the test. However, having to convince the investigator that they are in fact innocent during the test is arguably just as interesting. If you would like to see the mock crime video used for the guilty suspects, then please ask the experimenter at the end.

**Part 2 – Deception Test**

During part 2 you took part in a computerised version of the CIT, or experienced it face-to-face with an investigator, who was not aware of whether you were innocent or guilty, but was aware of the correct crime items. For innocent suspects your physiological responses to each item in each question should be similar across all questions indicating that the crime items did not stand out to you during the test. For the guilty suspect, the crime item in each question should have created a different physiological response. Detection rates and classification of "guilty" or "innocent" are based on these differences in physiological responding.

**Memory Check and Other Feedback**

For this test to be valid the suspect must remember the crime items. Therefore, guilty suspects took a short memory check at the end to ensure nothing was forgotten after the video presentation stage. Innocent participant was asked to guess which items they thought would be the crime ones to ensure that they couldn't guess the crime items better than chance alone.

Great lengths were taken in this study to make it realistic as possible whilst maintaining experiment control. This included: Asking you to watch a video from first-person and to image that you had carried out that event; Having you and the investigator try to replicate the investigator / suspect dynamic often displayed during police interviews. It can be difficult to create stimuli mock crime studies and therefore we appreciate the feedback requested on the last form.

**Finally:**

Thank you for taking part and we hope you found the experiment interesting and educational. If you have any future questions then please feel free to email the researchers (see below). Alternatively you can reference the text below which provides a thorough review of the literature: Verschuere, B., Ben-Shakhar, G., & Meijer, E. (Eds.). (2011). *Memory detection: Theory and application of the Concealed Information Test*. Cambridge University Press.

Contact Info: K.A.Wade@warwick.ac.uk; d.norman.3@warwick.ac.uk; m.newman.1@warwick.ac.uk; a.zahid.1@warwick.ac.uk

*Figure A.60. Debrief sheet for What do you know, Experiment 1-2 and similar to*

*Fading Memories, Experiment 1*

## Deception Study Debrief

Thank you for taking part in my deception detection study.

In this study, you took part in 3 concealed information tests (CIT). 2 physiological 'polygraph' CITs and a reaction time CIT.

The purpose of the first test (with the Warwick images) was to establish a baseline based on your specific physiological sensitivity for each measure (e.g. heart rate, respiration etc). This could then be used to determine which measures you response most on.

Test 2 was the primary test with the crime images. If you were in the guilty condition, you would have known which images related to the crime as you saw the crime video. You were also given a fake alibi which happens to be the same story as the innocent condition (although you did not see this video). If you were in the innocent condition, then you would have only seen the alibi images as you saw the non-crime video.

Using your physiological reactions to the images, this test can accurately discriminate between those who recognise and lie about the crime images and those who don't. My research is looking at different ways to measure these physiological measures in an attempt to: **1.** Measure them without physical contact and covertly; **2.** Create individualised scoring based on pre-test data and weighting of measures. **3.** Explore the effectiveness of the test on scenes of a crime.

Test 3, the reaction test is a newer method to try and detect knowledge of crime items. Typically, people respond consistently slower to the crime items (if they are aware of them) compared to random items and I am interested in comparing this method with the physiological test.

I will run other studies like this next academic year (such as trying different ways to beat the test!) so if know anyone else interested in taking part then get them to email me. If they would like to take part in this study, then I still have space in week 10 if they hurry!

Thank you again and I will contact all participants about their scores as soon as I have run 40 participants and scored the data. Remember you participant number (top right) so you know which score is yours when I send them out.

Have a great holiday,

*Figure A.61. Debrief sheet for Unobtrusive Measures Study*

## **APPENDIX 2**

### **PROGRAMS AND SCRIPTS**

```

SuperStrict

Include "Variables - Phys Paired (29-04-18).bmx" 'For Phys Paired Experiment
Include "Functions - Phys Paired (29-04-18).bmx"

'#####
'#####
'#####
'BASIC SETUP
DisplaySize(xres,yres)
DisplaySet()
ParticipantNo()
SignalOut()
SetBetweenCond(Participant)

'BUILD CIT STRUCTURE
BuildAllLevels()
TrialArrayStringEdit(CIT_Element_Ar,CITEdit_Ar)
BuildExperimentArray()
FillOutAr()
EditArrays()

CSVToArray(Im_Des_Ar,"ImageDescription")
ImageDescription()
MakeMasterArray(totalnotrials,36)
MakeQuestionArray()

'LOAD IMAGES
LoadImages(AllTrial_Ar,TotalNoTrials,ImageAddress)

'CHECK STRUCTURE VISUALLY
'Visualise_CIT()
'QuestionTest()

'RUN EXPERIMENT

RunPractice()

RunExperiment()

End
'#####
'#####
'#####

'RUN PRACTICE
-----
----- FUNCTION
Function RunPractice()

    HideMouse()
    Cls; Text("Press Key to Start Practice",40,255,255,255,xres/2,yres/2,1); Flip 1;
    WaitKey()

    'START CIT TEXT
    Cls; Text("Practice Question",80,255,255,255,xres/2,yres/2,1); Flip 1; wait_ms(1000);
    Cls; Flip; wait_ms(PreQ_Duration)

```

Figure A.64. Blitzmax Physiology CIT Stimuli Program – Main (pg 1/10)

```

'PRESENT QUESTION
Cls; TextHighlight("A prototype product was stolen from a secret lab.; Do you
recognize any of the following as the; Device  stolen from the
lab?",32,255,255,255,(xres/2),(yres/2),1); Flip 1; wait_ms(Present_Q_Duration)
Cls; Flip 1; wait_ms(500)

'PRESENT IMAGE and ISI

Local Image1:TImage = LoadImage(ImageAddress + "10.1.Irrelevant.png")
Local Image2:TImage = LoadImage(ImageAddress + "10.2.Irrelevant.png")
Local Image3:TImage = LoadImage(ImageAddress + "10.0.Probe.png")
Local Image4:TImage = LoadImage(ImageAddress + "10.3.Irrelevant.png")
Local Image5:TImage = LoadImage(ImageAddress + "10.4.Irrelevant.png")

DrawStimuli(Image1); wait_ms(3000); Cls; Flip 1; wait_ms(3000)
DrawStimuli(Image2); wait_ms(3000); Cls; Flip 1; wait_ms(3000)
DrawStimuli(Image3); wait_ms(3000); Cls; Flip 1; wait_ms(3000)
DrawStimuli(Image4); wait_ms(3000); Cls; Flip 1; wait_ms(3000)
DrawStimuli(Image5); wait_ms(3000); Cls; Flip 1; wait_ms(3000)

'END CIT TEXT
Cls; Text(("End of Practice"),50,255,255,255,xres/2,yres/2,1); Flip; wait_ms(500)

End Function
'-----

'RUN EXPERIMENT
'----- FUNCTION
Function RunExperiment()
    Local x:Int =0

    sound=LoadSound("Configs/End.wav")
    PlaySound sound

    HideMouse()
    Cls; Text("Press Key to Start",40,255,255,255,Xres/2,Yres/2,1); Flip
    WaitKey()

'SYNC MILLISECS TO ON THE SECOND TIME
    Repeat
    Until (MilliSecs() Mod 1000) = 0

    ResetArray(TempBetCondArray)
    Triggerout("StartTest")

    For Local d:Int = 0 To Condition_B_ar.length-1

        BetCondRepNo=(RepChecker(MasterArray[x,16],0,d,AllTrial_Ar.length,"BetCond"))
'Fill between condition rep array

        For Local c:Int = 0 To Epoch_ar.length-1

            EpochRepNo=(RepChecker(MasterArray[x,17],0,c,AllTrial_Ar.length,"Epoch"))
'Fill Epoch condition

            For Local b:Int = 0 To CIT_Ar.length-1

```

Figure A.65. Blitzmax Physiology CIT Stimuli Program – Main (pg 2/10)

```

        CITRepNo=(RepChecker(MasterArray[x,19],0,b,AllTrial_Ar.length,"CIT"))
'Fill CIT Rep array

        'GIVE BREAK BETWEEN CONDITIONS
        FlushKeys()

        'START CIT TEXT
        Cls; Text(("Question "+(b+1)+" of 12"),80,255,255,255,xres/2,yres/2,1);
Flip; wait_ms(500)

        Triggerout("StartCIT")
        wait_ms(PreQ_Duration)
        Triggerout("Question")

        'PRESENT QUESTION
        Cls; TextHighlight(MasterArray[x,23],32,255,255,255,(xres/2),(yres/2),1);
Flip 1; wait_ms(Present_Q_Duration)
        Cls; Flip 1; wait_ms(500)

        For Local a:Int =0 To Trial_Ar.length-1

            'ARRAY CHECKS

            TrialRepNo=(RepChecker(MasterArray[x,26],0,a,Alltrial_Ar.length,"Trial"))
            BufferCheck(a) 'Labels buffer items

            'TRIGGER OUT
            TriggerCheck(MasterArray[x,24]) 'sets trigger based on item

            'PRE IMAGE BLANK
            wait_ms(Pre_Image_Duration)
            Triggerout(MasterArray[x,24])

            'PRESENT IMAGE
            DrawStimuli((ImageArray[x])); wait_ms(ImageDuration)

            'ISI
            'Triggerout("Blank")
            Cls; Flip 1; wait_ms(InterStimuliInterval)

            'CSV OUT

            Outfile(MasterArray[x,0],MasterArray[x,1],MasterArray[x,2],MasterArray[x,3],MasterArray[x,4],MasterArray[x,5],MasterArray[x,6],MasterArray[x,7],MasterArray[x,8],MasterArray[x,9],MasterArray[x,10],MasterArray[x,11],MasterArray[x,12],MasterArray[x,13],MasterArray[x,14],BetCondRepNo,MasterArray[x,16],MasterArray[x,17],EpochRepNo,MasterArray[x,19],MasterArray[x,20],CITRepNo,(a+1),MasterArray[x,23],MasterArray[x,24],TrialRepNo,MasterArray[x,26],Buffer,MasterArray[x,28],String(MilliSecs()),MasterArray[x,30],MasterArray[x,31],MasterArray[x,32],MasterArray[x,33],MasterArray[x,34],Trigger)
            'Triggerout("Blank")

            'NEXT TRIAL
            x=x+1
            If KeyHit(Key_ESCAPE) Then a=999; b=999; c=999; d=999
        Next

        ResetArray(TempTrialArray)
        Triggerout("EndBlock")

        'END CIT TEXT
        Cls; Text(("End of Question "+(b+1)),50,255,255,255,xres/2,yres/2,1);
Flip;

```

Figure A.66. *Blitzmax Physiology CIT Stimuli Program – Main (pg 3/10)*



```

        wait_ms(PostCITDuration)

        Next
        FlushKeys()
        ResetArray(TempCITArray)

    Next

    ResetArray(TempEpochArray)

Next

    Triggerout("EndTest")
    Cls; Text("Test Complete. Press Signal the
Experiment",40,255,255,255,Xres/2,Yres/2,1); Flip 1; WaitKey()

    sound=LoadSound("Configs/End.wav")
    PlaySound sound

End Function
'-----
'-----

'#####
'#####
'#####

'CHECK IF ITEM
BUFFER-----
'-----
Function BufferCheck(TrialPos:Int)
    If TrialPos=0 Then Buffer="1"
    If trialPos<>0 Then Buffer="0"
End Function
'-----
'-----

'BUILD EACH LEVEL
'-----
'----- FUNCTION
Function BuildAllLevels()
    BuildSingleArray(Trial_Element_Ar,CITSize,"Trials
",NoProbes,NoTargets,NoIrrelevants)
    BuildSingleArray(CIT_Element_Ar,NoCITs,"CIT ",NoProbes,NoTargets,NoIrrelevants)
    BuildSingleArray(Condition_W_Element_Ar,NoCondition_W,"Condition_W
",NoProbes,NoTargets,NoIrrelevants)
    BuildSingleArray(Epoch_Element_Ar,NoEpoch,"Epoch
",NoProbes,NoTargets,NoIrrelevants)
    BuildSingleArray(Condition_B_Element_Ar,NoCondition_B,"Condition_B
",NoProbes,NoTargets,NoIrrelevants)
End Function
'-----
'-----

```

Figure A.67. Blitzmax Physiology CIT Stimuli Program – Main (pg 4/10)

```

'BUILD TRIAL ARRAY
-----

Function BuildExperimentArray:String[]()
    Local d:Int=0
    Local q:Int=0
    Local e:Int=0
    Local f:Int=0
    Local g:Int=0
    Local o:Int=0
    Local x:Int=0

    ShuffleRepeats(Condition_B_Ar,Condition_B_Element_Ar,Condition_B_Unit_Ar,Condition_B_E
lement_Shuffle,Condition_B_Unit_Shuffle,Condition_B_Element_Reps,Condition_B_Unit_Reps)
    For Local s:Int = 0 To Condition_B_Ar.length-1
        AllCondition_B_Ar[g] = Condition_B_Ar[s]
        g=g+1

    ShuffleRepeats(Epoch_Ar,Epoch_Element_Ar,Epoch_Unit_Ar,Epoch_Element_Shuffle,Epoch_Uni
t_Shuffle,Epoch_Element_Reps,Epoch_Unit_Reps)
    For Local u:Int=0 To Epoch_Ar.length-1
        AllEpoch_Ar[e] = Epoch_Ar[u]
        e=e+1

    ShuffleRepeats(Condition_W_Ar,Condition_W_Element_Ar,Condition_W_Unit_Ar,Condition_W_E
lement_Shuffle,Condition_W_Unit_Shuffle,Condition_W_Element_Reps,Condition_W_Unit_Reps)
    For Local y:Int=0 To Condition_W_Ar.length-1
        AllCondition_W_Ar[o] = Condition_W_Ar[y]
        o=o+1
    Next
    If x=0 Then
        ShuffleRepeats(CIT_Ar,CIT_Element_Ar,CIT_Unit_Ar,CIT_Element_Shuffle,CIT_Unit_Shuffle,CIT_
Element_Reps,CIT_Unit_Reps)
        x=1
        For Local w:Int=0 To CIT_Ar.length-1
            AllCIT_Ar[d] = CIT_Ar[w]
            d=d+1

        ShuffleRepeats(Trial_Ar,Trial_Element_Ar,Trial_Unit_Ar,Trial_Element_Shuffle,Trial_Uni
t_Shuffle,Trial_Element_Reps,Trial_Unit_Reps)
        For Local V:Int= 0 To Trial_Ar.length -1
            AllTrial_Ar[q] = String(CIT_Ar[w].split(" ")[1]) + "." + Trial_Ar[v]
            q=q+1
        Next
    Next
Next
Next
End Function
'-----

'EDIT ARRAYS BASED ON
CONDITONS-----FUNCTION
Function EditArrays()
    ArrayStringEdit(AllCondition_W_Ar,"Condition_W 1",ConditionW1)
    ArrayStringEdit(AllCondition_W_Ar,"Condition_W 2",ConditionW2)
    ArrayStringEdit(AllCondition_B_Ar,"Condition_B 1",ConditionB1)
    ArrayStringEdit(AllCondition_B_Ar,"Condition_B 2",ConditionB2)
    ArrayStringEdit(Condition_W_Trial_Ar,"Condition_W 1",ConditionW1)
    ArrayStringEdit(Condition_W_Trial_Ar,"Condition_W 2",ConditionW2)
    ArrayStringEdit(Condition_B_Trial_Ar,"Condition_B 1",ConditionB1)

```

Figure A.68. Blitzmax Physiology CIT Stimuli Program – Main (pg 5/10)

```

    ArrayStringEdit(Condition_B_Trial_Ar,"Condition_B 2",ConditionB2)
End Function
'-----

'FILL OUT ARRAYS
'-----FUNCTION
Function FillOutAr()
    FillArrayOut(Condition_B_Trial_Ar,AllCondition_B_Ar)
    FillArrayOut(Epoch_Trial_Ar,AllEpoch_Ar)
    FillArrayOut(Condition_W_Trial_Ar,AllCondition_W_Ar)
    FillArrayOut(CIT_Trial_Ar,AllCIT_Ar)
End Function
'-----

'IMAGE DESCRIPTION ARRAY
'-----FUNCTION
Function ImageDescription()
For Local j:Int=0 To (Im_Des_Ar.length/2)-1
    For Local i:Int=0 To TotalNoTrials-1
        If AllTrial_Ar[i] = Im_Des_Ar[j,0] Then ImageDescription_Ar[i] = Im_Des_Ar[j,1]
    Next
Next
End Function
'-----

'MAKE MASTER ARRAYS
'-----FUNCTION
Function MakeMasterArray(Length:Int,Width:Int)

For Local l:Int = 0 To Length-1
    MasterArray[l,0]= Researcher
    MasterArray[l,1]= Experiment
    MasterArray[l,2]= Stage
    MasterArray[l,3]= Stimuli_Set
    MasterArray[l,4]= TimeStamp
    MasterArray[l,5]= Participant
    MasterArray[l,6]= IDNo
    MasterArray[l,7]= Bet_Sbj_Cond
    MasterArray[l,8]= Q_Loc_PreImage
    MasterArray[l,9]= Q_Loc_Image
    MasterArray[l,10]= Q_loc_PostImage
    MasterArray[l,11]= ImageOnsetType
    MasterArray[l,12]= ImageLoc
    MasterArray[l,13]= ImageDuration
    MasterArray[l,14]= Condition_B_Trial_Ar[l]
    MasterArray[l,15]= BetCondRepNo
    MasterArray[l,16]= condition_W_Trial_Ar[l]
    MasterArray[l,17]= Epoch_Trial_Ar[l]
    MasterArray[l,18]= EpochRepNo
    MasterArray[l,19]= CIT_Trial_Ar[l]
    MasterArray[l,20]= CIT_Trial_Ar[l].split(" ")[1]
    MasterArray[l,21]= CITRepNo
    MasterArray[l,22]= "CITPosition"
    MasterArray[l,23]= ""
    MasterArray[l,24]= AllTrial_Ar[l].split(".")[2]
    MasterArray[l,25]= TrialRepNo
    MasterArray[l,26]= AllTrial_Ar[l]
    MasterArray[l,27]= Buffer

```

Figure A.69. Blitzmax Physiology CIT Stimuli Program – Main (pg 6/10)

```

MasterArray[1,28]= (1+1)
MasterArray[1,29]= MilliSecs()
MasterArray[1,30]= AllTrial_Ar[1]
MasterArray[1,31]= ImageDescription_Ar[1]
MasterArray[1,32]= "ImageSize"
MasterArray[1,33]= "ImageLum"
MasterArray[1,34]= InterStimuliInterval
MasterArray[1,35]= Trigger

Next
End Function
'-----

'MAKE QUESTION ARRAYS
'-----
FUNCTION
Function MakeQuestionArray() '-Temporary
For Local r:Int=0 To TotalNoTrials-1
    For Local q:Int=0 To NoCITs-1
        If MasterArray[r,20] = (q+1) Then MasterArray[r,23]= Question_Ar[q]
    Next
Next
End Function
'-----

'OUTFILE
'-----
FUNCTION
Function
Outfile(Researcher:String, Experiment:String, Stage:String, Stimuli_Set:String, Timestamp:Stri
ng, Participant:String, IDNo:String, Bet_Sbj_Cond:String, Q_Loc_PreImage:String, Q_Loc_Image:St
ring, Q_loc_PostImage:String, ImageOnsetType:String, ImageLoc:String, ImageDuration:String, Bet
_Epoch_Cond:String, Bet_Epoch_CondRep:String, With_Epoch_Cond:String, Epoch:String, EpochRep:S
tring, CIT:String, CITNo:String, CITRep:String, CITPosition:String, Question:String, Item:String
, ItemRep:String, ItemString:String, Buffer:String, TrialNumber:String, TrialTime:String, ImageS
tring:String, ImageDescription:String, ImageSize:String, ImageLum:String, ISI:String, Trigger:S
tring)
    Local filename:String = "Phys Data/" + Participant + "(" + Experiment + ").csv"
    If FileType(filename) = 0 Then CreateFile(filename)
    Local Stream:TStream = OpenStream(filename)
    SeekStream(stream, stream.Size())
    If stream.Size() = 0 Then WriteLine stream,
"Researcher,Experiment,Stage,Stimuli_Set,Timestamp,Participant,IDNo,Bet_Sbj_Cond,Q_Loc_Pre
Image,Q_Loc_Image,Q_loc_PostImage,ImageOnsetType,ImageLoc,ImageDuration,Bet_Epoch_Cond,Bet
_Epoch_CondRep,With_Epoch_Cond,Epoch,EpochRep,CIT,CITNo,CITRep,CITPosition,Question,Item,I
temRep,ItemString,Buffer,TrialNumber,TrialTime,ImageString,ImageDescription,ImageSize,Imag
eLum,ISI,Trigger"
    WriteLine(stream,
Researcher+", "+Experiment+", "+Stage+", "+Stimuli_Set+", "+Timestamp+", "+Participant+", "+IDNo
+", "+Bet_Sbj_Cond+", "+Q_Loc_PreImage+", "+Q_Loc_Image+", "+Q_loc_PostImage+", "+ImageOnsetTyp
e+", "+ImageLoc+", "+ImageDuration+", "+Bet_Epoch_Cond+", "+Bet_Epoch_CondRep+", "+With_Epoch_C
ond+", "+Epoch+", "+EpochRep+", "+CIT+", "+CITNo+", "+CITRep+", "+CITPosition+", "+Question+", "+I
tem+", "+ItemRep+", "+ItemString+", "+Buffer+", "+TrialNumber+", "+TrialTime+", "+ImageString+",
"+ImageDescription+", "+ImageSize+", "+ImageLum+", "+ISI+", "+Trigger")
    CloseStream(stream)
EndFunction
'-----

'VISUALISE ALL

```

Figure A.70. Blitzmax Physiology CIT Stimuli Program – Main (pg 7/10)

```

LEVELS'-----
-----
Function Visualise_CIT()

    Cls

    DrawBox(255,255,255,(xres*0.01),(yres*0.01),(xres*0.98),(yres*0.98),1)
    Text("CIT STRUCTURE VISUAL INSPECTION",20,0,0,0,(xres*0.35),(yres/30)*1,0)

    Text(NoCondition_B + "x Between Condition (Grey) - Number of Condition_Bs in
Experiment",20,0,0,0,(xres*0.025),(yres/30)*3,0)
    Text(NoEpoch + "x Epoch (Purple) - Epochs in between condition",20,0,0,0,(xres*
0.025),(yres/30)*4,0)
    Text(NoCondition_W + "x Within Condition (Blue) - Number of Condition_Ws in
Epoch",20,0,0,0,(xres*0.025),(yres/30)*5,0)
    Text(NoCITs + "x CITs (Green) - CITs in Within Condition",20,0,0,0,(xres*
0.025),(yres/30)*6,0)
    Text(CITSize + "x Trials (Probe=Yellow, Target=Orange, Irrelevants=Red) - Trials in a
CIT",20,0,0,0,(xres*0.025),(yres/30)*7,0)
    Text(AllTrial_Ar.Length + " = Total Trials",20,0,0,0,(xres*0.025),(yres/30)*8,0)

    If NoCondition_B>1 Then VisualiseStructure(AllCondition_B_Ar,9,128,128,128)
    VisualiseStructure(AllEpoch_Ar,10,200,128,200)
    If NoCondition_W>1 VisualiseStructure(AllCondition_W_Ar,11,128,128,255)
    VisualiseStructure(AllCIT_Ar,12,75,255,128)
    VisualiseStructure(AllTrial_Ar,13,0,0,0)

    'Zoomed in single CIT Visual
    Text("Single CIT Zoom (below)",20,0,0,0,(xres*0.025),(yres/30)*20,0)
    VisualiseStructure(Trial_Ar,21,0,0,0)

    TrialVisual("Pre-Q",PreQ_Duration,"Question", Present_Q_Duration,"Pre-
Image",Pre_Image_Duration,"Image",ImageDuration,"ISI",InterStimuliInterval,"Post-
Trail",PostCITDuration,yres*0.85)

    SavePixmapPNG((GrabPixmap(0,0,xres,yres)),"Phys Data/"+Experiment+"_CIT_Data/" +
Participant + "(" + Experiment + ") CITStructure.png")

    SetScale(1,1)
    Flip

    WaitKey()

End Function
'-----
-----

'VISUAL OF TRIAL TIMES
-----
-----

Function
TrialVisual(S1:String,B1:Int,S2:String,B2:Int,S3:String,B3:Int,S4:String,B4:Int,S5:String,
B5:Int,S6:String,B6:Int,Level:Float)

    Local startpos:Float=xres*0.02
    Local endpos:Float=(xres*0.96)
    Local totaltime:Float=(B1+B2+B3+B4+B5+B6)
    Local CITTime:Float=totaltime*Trial_Element_Ar.length
    Local ExperimentTime:Float=CITTime*AllCIT_Ar.Length

    Local a:Float= (B1/totaltime)*endpos
    Local b:Float= (B2/totaltime)*endpos
    Local c:Float= (B3/totaltime)*endpos

```

Figure A.71. Blitzmax Physiology CIT Stimuli Program – Main (pg 8/10)

```

Local d:Float= (B4/totaltime)*endpos
Local e:Float= (B5/totaltime)*endpos
Local f:Float= (B6/totaltime)*endpos

Text("Timings",20,0,0,0,startpos+5,Level-60,0)
Text("Trial time = "+Int(totaltime)+"ms",10,0,0,0,startpos+5,Level-40,0)
Text("CIT time = "+Int(CITTime)/1000+"s",10,0,0,0,startpos+5,Level-30,0)
Text("Experiment time = "+Int(ExperimentTime)/60000+"mins",10,0,0,0,startpos+
5,Level-20,0)

Drawbox(128,128,255,(startpos),Level,a,30,1)
Text(S1,10,0,0,0,startpos+5,Level,0)
Text(B1+"ms",10,0,0,0,startpos+5,Level+10,0)

Drawbox(255,255,128,(startpos+a),Level,b,30,1)
Text(S2,10,0,0,0,(startpos+5+a),Level,0)
Text(B2+"ms",10,0,0,0,(startpos+5+a),Level+10,0)

Drawbox(128,128,255,(startpos+a+b),Level,c,30,1)
Text(S3,10,0,0,0,(startpos+5+a+b),Level,0)
Text(B3+"ms",10,0,0,0,(startpos+5+a+b),Level+10,0)

Drawbox(128,255,128,(startpos+a+b+c),Level,d,30,1)
Text(S4,10,0,0,0,(startpos+5+a+b+c),Level,0)
Text(B4+"ms",10,0,0,0,(startpos+5+a+b+c),Level+10,0)

Drawbox(128,128,255,(startpos+a+b+c+d),Level,e,30,1)
Text(S5,10,0,0,0,(startpos+5+a+b+c+d),Level,0)
Text(B5+"ms",10,0,0,0,(startpos+5+a+b+c+d),Level+10,0)

Drawbox(128,128,255,(startpos+a+b+c+d+e),Level,f,30,1)
Text(S6,10,0,0,0,(startpos+5+a+b+c+d+e),Level,0)
Text(B6+"ms",10,0,0,0,(startpos+5+a+b+c+d+e),Level+10,0)

End Function
'-----

'CHECK TRIGGER
ITEM-----

Function TriggerCheck(Item:String)
    If item = "Probe" Then Trigger = "102"
    If item = "Irrelevant" Then Trigger = "103"
    If item = "Target" Then Trigger = "104"
End Function
'-----

'CHECK REPETITION
NUMBER-----

Function RepChecker:String(Item:String,Rep:Int,Element:Int,HowMany:Int,Level:String)
    If level = "Trial"
        tempTrialArray[element] = item
        For Local j:Int=0 To howmany-1
            If TempTrialArray[j] = Item Then rep = rep + 1
        Next
        Return Rep
    Else If Level="CIT"
        tempCITArray[element] = item
        For Local j:Int=0 To howmany-1
            If TempCITArray[j] = Item Then rep = rep + 1
        Next
    End If
End Function

```

Figure A.72. Blitzmax Physiology CIT Stimuli Program – Main (pg 9/10)

```

        Return Rep
    Else If Level="Epoch"
        tempEpochArray[element] = item
        For Local j:Int=0 To howmany-1
            If TempEpochArray[j] = Item Then rep = rep + 1
        Next
        Return Rep
    Else If Level="BetCond"
        tempBetCondArray[element] = item
        For Local j:Int=0 To howmany-1
            If TempBetCondArray[j] = Item Then rep = rep + 1
        Next
        Return Rep
    End If
End Function
'-----
'-----

Function QuestionTest()
Cls; Text(Question_Ar[0],35,255,255,255,xres/2,yres/2,1); Flip; WaitKey();
Cls; Text(Question_Ar[1],35,255,255,255,xres/2,yres/2,1); Flip; WaitKey();
Cls; Text(Question_Ar[2],35,255,255,255,xres/2,yres/2,1); Flip; WaitKey();
Cls; Text(Question_Ar[3],35,255,255,255,xres/2,yres/2,1); Flip; WaitKey();
Cls; Text(Question_Ar[4],35,255,255,255,xres/2,yres/2,1); Flip; WaitKey();
Cls; Text(Question_Ar[5],35,255,255,255,xres/2,yres/2,1); Flip; WaitKey();
Cls; Text(Question_Ar[6],35,255,255,255,xres/2,yres/2,1); Flip; WaitKey();
Cls; Text(Question_Ar[7],35,255,255,255,xres/2,yres/2,1); Flip; WaitKey();
End Function

```

Figure A.73. *Blitzmax Physiology CIT Stimuli Program – Main (pg 10/10)*

```

'ARRAY STRING EDIT
-----
----- FUNCTION
'Change certain individual string elements (ArrayItems) in an array (Array) with another
fixed string (NewArrayItem)
Function ArrayStringEdit:String[](Array:String[],ArrayItem:String,NewArrayItem:String)
    For Local i:Int =0 To Array.length-1
        If Array[i] = ArrayItem Then Array[i] = NewArrayItem
    Next
End Function
'-----

'BUILD SINGLE CIT
FUNCTION-----
----- FUNCTION
Function BuildSingleArray:String[]
(Array:String[],Number:Int,Label:String,NoProbes:Int,NoTargets:Int,NoIrrelevants:Int)
    If Label <> "Trials "
        For Local y:Int=0 To Array.length-1
            For Local Xn:Int=0 To Number-1
                Array[y] = Label + (Xn+1)
                y=y+1
            Next
        Next
    Else If Label = "Trials "
        For Local x:Int=0 To Array.length-1
            For Local PN:Int=0 To NoProbes-1
                Array[x] = (PN)+".Probe"
                x=x+1
            Next
            For Local TN:Int=0 To NoTargets-1
                Array[x] = (TN)+".Target"
                x=x+1
            Next
            For Local IN:Int=0 To NoIrrelevants-1
                Array[x] = (IN+1)+".Irrelevant"
                x=x+1
            Next
        Next
    End If
    Return Array
End Function
'-----

'READING IN CSV TO ARRAY
-----
-----FUNCTION
Function CSVToArray:String[,] (Array:String[,],Filename:String)

    Local Textstream:TStream = ReadStream(ImageAddress+Filename+".csv")
    Local LinestoRead:Int = Array.length
    Local TextString:String = ""

    For Local i:Int = 0 To (array.length/2) -1
        TextString = ReadLine(Textstream)
        Array[i,0] = TextString.Split(",")[0]
        Array[i,1] = TextString.Split(",")[1]
    Next
    Eof(Textstream)
    Return Array

```

Figure A.74. Blitzmax Physiology CIT Stimuli Program – Functions (pg 1/13)



```

End Function

'-----
'-----

'DRAW STIMULI
'-----
'----- FUNCTION
Function DrawStimuli(Image:TImage)
    Cls
    ScaleImage(Image,ImageScale)
    DrawImage(Image,(xres/2),(yres/2))
    SetScale(1,1)
    Flip
End Function

'-----
'-----

'GRAPHICS
'+++++
+++++

'DISPLAYSIZE-----
'----- FUNCTION
    'Get system resolution
    Function DisplaySize(Xres:Int Var, Yres:Int Var)
        Extern "Win32"
            Function GetSystemMetrics:Int(Axis:Int)
        End Extern
        xRes:Int=GetSystemMetrics(0)      'x resolution of the screen from the Win32
command yRes:Int=GetSystemMetrics(1)    'y resolution of the screen from the Win32
command
    End Function
'-----
'-----

'DISPLAY
SETTINGS-----
'----- FUNCTION
    'Setting graphics resolution
    Function DisplaySet()
        SetGraphicsDriver GLMax2DDriver()
        Graphics Xres,Yres,WindowMode
        SetClsColor(Background_R,Background_G,Background_B)
        SetMaskColor(Background_R,Background_G,Background_B)
        AutoMidHandle(1)
        SetBlend Alphablend
        Cls
    EndFunction
'-----
'-----

'+++++
+++++

'DRAW BOX
'-----
'-----
Function DrawBox(r:Int,g:Int,b:Int,x:Int,y:Int,w:Int,h:Int,Boarder:Int)
    SetScale(1,1)
    SetColor(r,g,b)

```

Figure A.75. Blitzmax Physiology CIT Stimuli Program – Functions (pg 2/13)

```

    If Boarder=0
        DrawRect(x,y,w,h)
    Else If Boarder=1
        DrawRect(x,y,w,h)
        SetColor(0,0,0)
        DrawLine(x,y,x+w-1,y)
        DrawLine(x+w-1,y,x+w-1,y+h-1)
        DrawLine(x+w-1,y+h-1,x,y+h-1)
        DrawLine(x,y+h-1,x,y)
    Else If Boarder=2
        SetColor(0,0,0)
        DrawLine(x,y,x+w-1,y)
        DrawLine(x+w-1,y,x+w-1,y+h-1)
        DrawLine(x+w-1,y+h-1,x,y+h-1)
        DrawLine(x,y+h-1,x,y)
    End If
    'SetColor(128,128,128)
End Function
'-----

'CREATE FIXATION BETWEEN TRIALS
'-----
- FUNCTION
Function fixation(ms:Int,size:Int=4,x:Int,y:Int,shape:String="cross",red:Int=
180,green:Int=180,blue:Int=180);
    Local R:Int;Local G:Int; Local B:Int
    GetColor(R,G,B);
    SetColor(red,green,blue)
    Cls
    Select shape
        Case "square" DrawRect(x-(size/2), y-(size/2),size,size)
        Case "circle" DrawOval(x-(size/2), y-(size/2),size,size)
        Case "cross" DrawLine(x, y-(size/2), x,y+(size/2))
                    DrawLine(x-(size/2), y, x+(size/2), y)
    End Select
    SetColor(R,G,B)
    Flip 1
    wait_ms(ms)
    Cls
End Function
'-----

'FILL OUT ARRAY
'-----
'Fill out NewArray with Array in a balanced manner
Function FillArrayOut:String[] (NewArray:String[],Array:String[])
    Local x:Int = 0
    For Local j:Int = 0 To Array.length-1
        For Local i:Int=0 To (NewArray.length/Array.length)-1
            NewArray[x] = Array[j]
            x=x+1
        Next
    Next
    Return NewArray
End Function
'-----

'FADE
STIMULI-----
----- FUNCTION

```

Figure A.74. Blitzmax Physiology CIT Stimuli Program – Functions (pg 3/13)

```

Function FadeStimuli(Image:TImage)

    Local i:Int=0
    Local time:Int=1
    Local alpha:Float = 0

    Cls
    SetBlend(ALPHABLEND)
    ScaleImage(Image,ImageScale)

    Local t:Int=MilliSecs()
    Local alphastep:Float = ImageDuration/FadeSteps

    For time:Int=1 To FadeSteps

        i = MilliSecs()

        Cls; SetAlpha(alpha); DrawImage(Image,(xres/2),(yres/2)); Flip 1

        alpha=(alpha+(1/alphastep))

        If alphastep > 17 Then Wait_ms((ImageDuration/FadeSteps) - (MilliSecs() - i))
    Next

    SetScale(1,1)

    Print (MilliSecs() - t)

End Function
'-----
'GET TEXT INPUT FROM USER
'-----
-----FUNCTION
Function gInput:String(x:Int,y:Int,prompt:String = "?")
    Local m:String=""
    While 1
        Cls
        SetColor(255,255,255)
        DrawText prompt$m$,10,10
        Local nextKey:Int = GetChar()
        If nextKey
            If nextKey = KEY_ENTER
                Return m
            Else If nextKey = KEY_BACKSPACE
                'l = Len(m$)
                m = m[..Len(m)-1]
            Else
                m$ = m$ + Chr$(nextKey)
            EndIf
        EndIf
        Flip True
    Wend
End Function
'-----

Function IsEven:Int(number:Int)
    Return (number Mod 2) = 0
End Function

'LOAD IMAGES
'-----

```

Figure A.75. Blitzmax Physiology CIT Stimuli Program – Functions (pg 5/13)

```

----- FUNCTION
Function LoadImages:String[] (Array:String[], NoImages:Int, ImageAddress:String)
  For Local v:Int=0 To NoImages-1
    ImageArray[v] = LoadImage(ImageAddress + Array[v] + ".png")
    Loadingbar(0, "Loading Images", NoImages)
  Next
  Loadingbar(1, "Loading Images Complete", NoImages)
End Function
'-----

'LOADING
----- FUNCTION
Function LoadingBar(Stage:Int, Text:String, NumBars:Int)
If NumBars>10
  'Draws a loading bar with text
  SetScale(1,1)
  Counter = Counter + 1
  If stage=0
    If (counter Mod (NumBars/10))=0
      Loading = Loading + "|"
      Cls
      DrawBox(128,128,128,(xres*0.47),(yres*0.5),90,14,2)
      DrawText(Loading,(xres*0.47),(yres*0.5))
      DrawText(Text,(xres*0.47),(yres*0.45))
      Flip
    End If
  Else If stage=1
    Counter = 0
    Loading = "|"
    Cls
    DrawText(Text,(xres*0.47),(yres*0.5))
    Flip
  End If
End If
End Function
'-----

```

Figure A.76. Blitzmax Physiology CIT Stimuli Program – Functions (pg 6/13)

```

'PARTICIPANT
NUMBER-----FUNCTION
    'Get participant number
Function ParticipantNo()
    Repeat
    Cls
    Participant= ginput(20,20,"Participant Number: ")
    Until (Participant.length <>"")
    IDNo = Participant+"_"+Experiment
End Function
'-----

'ASK FOR SIGNAL
OUT-----FUNCTION
    'Get participant number
Function SignalOut()
    Repeat
    Cls
    SendSignals= ginput(20,20,"Output Digital Signals (Yes/No): ")
    Until (SendSignals.length <>"")

End Function
'-----

'PRINT STRING
ARRAY-----FUNCTION
    Function PrintStringArray:String[](Array:String[],Name:String)
        Print "-----"
        Print Name
        Print "-----"
        Local Array_Size:Int = Array.length
        For Local z:Int=0 To Array_Size -1
            Print Array[z]
        Next
    End Function
'-----

'PRINT STRING
ARRAY-----FUNCTION
    Function PrintMultiStringArray:String[,](Array:String[,],Name:String)
        Print "-----"
        Print Name
        Print "-----"
        Local Array_Size:Int = Array.length
        For Local z:Int=0 To (Array_Size/2) -1
            Print Array[z,0] + " , " + Array[z,1]
        Next
    End Function

```

Figure A.77. Blitzmax Physiology CIT Stimuli Program – Functions (pg 7/13)

```

'REPEAT ELEMENTS IN ARRAY
-----
FUNCTION
Function RepeatElements:String[](Array:String[],NewArray:String[],Reps:Int)
Local w:Int=0
    w=0
    For Local i:Int = 0 To Array.length-1
        For Local j:Int =0 To Reps-1
            NewArray[w]=Array[i]
            w=w+1
        Next
    Next
Return NewArray
End Function
'-----

'REPEAT UNITS IN ARRAY
-----
FUNCTION
Function RepeatUnits:String[](Array:String[],NewArray:String[],Reps:Int)
Local w:Int=0
    w=0
    For Local i:Int = 0 To Reps-1
        For Local j:Int =0 To Array.length-1
            NewArray[w]=Array[j]
            w=w+1
        Next
    Next
Return NewArray
End Function
'-----

'RESET AN
ARRAY-----
Function ResetArray:String[](Array:String[])
    For Local i:Int =0 To Array.length-1
        Array[i] = ""
    Next
End Function
'-----

'SCALE STIMULI
-----
FUNCTION
Function ScaleImage(Image:TImage,ImageScale:Float)
    Local x:Float = ImageHeight(Image)
    Local y:Float = ImageWidth(Image)
    SetScale((xres/(y/ImageScale)),(yres/(x/ImageScale)))
End Function
'-----

'SET BETWEEN SUBJECT
COND-----
Function SetBetweenCond(Participant:String)

```

Figure A.78. *Blitzmax Physiology CIT Stimuli Program – Functions (pg 8/13)*

```

    Local P:Float = Participant:String.Tofloat()
    If (P Mod 2) = 0
        ConditionW1 ="Fade"
        ConditionW2="NoFade"
    Else
        ConditionW1 ="NoFade"
        ConditionW2="Fade"
    End If
End Function
'-----
'-----

'SHUFFLEREPEATS
'-----
'----- FUNCTION

Function ShuffleRepeats:String[]
(Ar:String[],Element_Ar:String[],Unit_Ar:String[],Element_Shuffle:Int,Unit_Shuffle:Int,Element_Reps:Int,Unit_Reps:Int)

    If Element_Shuffle = 1 Then ShuffleStringArray(Element_Ar)
    RepeatElements((Element_Ar),(Unit_Ar),(Element_Reps))
    If Unit_Shuffle = 1 Then ShuffleStringArray(Unit_Ar)
    RepeatUnits((Unit_Ar),(Ar),(Unit_Reps))
    Return Ar

End Function
'-----
'-----

'SHUFFLE ARRAY
'-----
'----- FUNCTION

Function ShuffleStringArray:String[](Array:String[])
    Local m1:Int=0
    Local m2:Int=0
    Local element1:String=0
    Local element2:String=0
    Local a:Int=0
    Repeat
        a=0
        For Local i:Int = 0 To 10000
            m1 = Rand(0,Array.length-1)
            m2 = Rand(0,Array.length-1)
            element1 = Array[m1]
            element2 = Array[m2]
            Array[m1] = element2
            Array[m2] = element1
        Next

        If Array[0].Contains("Probe")
            a=1
        End If
        If Array[0].Contains("Target")
            a=1
        End If

    Until a=0
    Return Array

End Function
'-----
'-----

```

Figure A.79. Blitzmax Physiology CIT Stimuli Program – Functions (pg 9/13)

```

' TEXT SETUP
' ++++++
+++++

' TEXT
FUNCTION----- FUNCTION
' Draw Text to screen
Function Text(Text:String,SizeFont:Int,R:Int,G:Int,B:Int,Xpos:Int,Ypos:Int,Centre:Int)
    If SizeFont =0 Then SizeFont = DefaultFontSize
    Local FontB:TImageFont=LoadImageFont("C:\WINDOWS\Fonts
\"+BasicFontType+".ttf",SizeFont)
    SetImageFont FontB
    SetColor(R,G,B)
    SetBlend ALPHABLEND

    If text.contains(";")=0

        If Centre = 1 Then DrawText(text,Xpos-(TextWidth(text)/2),Ypos-sizefont/2)
        If Centre = 0 Then DrawText(text,Xpos,Ypos)

    Else If text.contains(";")>0
        If Centre = 1
            DrawText((text.split(";")[0]),Xpos-(TextWidth(text.split(";")
[0])/2),Ypos-(2*sizefont))
            DrawText((text.split(";")[1]),Xpos-(TextWidth(text.split(";")
[1])/2),Ypos)
            DrawText((text.split(";")[2]),Xpos-(TextWidth(text.split(";")
[2])/2),Ypos+(2*sizefont))
        End If

        If Centre = 0
            DrawText((text.split(";")[0]),Xpos,Ypos-(2*sizefont))
            DrawText((text.split(";")[1]),Xpos,Ypos)
            DrawText((text.split(";")[2]),Xpos,Ypos+(2*sizefont))
        End If
    End If

    SetColor(255,255,255)
    SetScale(1,1)
End Function
'-----

' TEXT FUNCTION
Highlight----- FUNCTION
' Draw Text to screen - custom to highlight first word of sentence 3
Function
TextHighLight(Text:String,SizeFont:Int,R:Int,G:Int,B:Int,Xpos:Int,Ypos:Int,Centre:Int)
    If SizeFont =0 Then SizeFont = DefaultFontSize
    Local FontB:TImageFont=LoadImageFont("C:\WINDOWS\Fonts
\"+BasicFontType+".ttf",SizeFont)

    Local tx:String=""
    Local tx2:String=""

    tx = text.split(";")[2]
    tx = tx.split(" ")[0]
    tx2 = text.split(";")[2]
    'tx2 = tx2.split("#")[1]

```

Figure A.80. Blitzmax Physiology CIT Stimuli Program – Functions (pg 10/13)



```

Else
    Local Label:Short=0

    If TrigType="StartTest" Then Label = 100
    If TrigType="StartCIT" Then Label = 101
    If TrigType="Probe" Then Label = 102
    If TrigType="Irrelevant" Then Label = 103
    If TrigType="Target" Then Label = 104
    If TrigType="EndBlock" Then Label = 105
    If TrigType="EndTest" Then Label = 106
    If TrigType="Question" Then Label = 107
    If TrigType="Blank" Then Label = 108
    If TrigType="109" Then Label = 109

    If Not 0
        Local result:Byte=out32(LPT1,Label)
        wait_ms(10)
        result=out32(LPT1,0)
    EndIf
EndIf

End Function
'-----
'-----

'TIME (Stopwatch)
'-----
'----- FUNCTION
Function Time(Location:Int)
    If Location = 0 Then startstopwatch = MilliSecs()
    If Location = 1
        endstopwatch = MilliSecs()
        Print (endstopwatch-startstopwatch)
    End If
End Function
'-----
'-----

'VISUALISE EACH
LEVEL-----
'-----

Function VisualiseStructure:String[] (Array:String[], Level:Int, R:Int, G:Int, B:Int)

    Local startpos:Float=xres*0.02
    Local endpos:Float=(xres*0.96)
    Local Element_Width:Float=(endpos/Array.length)
    Local Element_Position:Float=(yres/30)*Level
    Local Element_Height:Float=20

    For Local n:Int=0 To Array.length-1
        If Array=AllTrial_Ar 'For Trial Array only as boxes get small
            If Array.length > 20 Then Element_Height=70
            If (Array[n].split(".")[2]) = "Probe" Then
                Drawbox(255,255,75,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_Height),1)
            If (Array[n].split(".")[2]) = "Target" Then
                Drawbox(255,128,75,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_Height),1)
            If (Array[n].split(".")[2]) = "Irrelevant"
                If (Array[n].split(".")[1])="1" Then
                    Drawbox(255,125,125,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_Height),1)
                If (Array[n].split(".")[1])="2" Then

```

Figure A.81. Blitzmax Physiology CIT Stimuli Program – Functions (pg 11/13)

```

Drawbox(255,100,100,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_H
eight),1)
    If (Array[n].split(".")[1])="3" Then
Drawbox(255,75,75,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_Hei
ght),1)
    If (Array[n].split(".")[1])="4" Then
Drawbox(255,50,50,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_Hei
ght),1)
    End If

    If Array.length > 20
    SetRotation (270)
    Text(Array[n],8,0,0,0,startpos+(Element_Width*n),(Element_Position+65),0)
    SetRotation(0)
    Else
    Text(Array[n],10,0,0,0,startpos+(Element_Width*n)+5,(Element_Position)+5,0)
    End If

    Else If Array=Trials_Ar
    If Array.length > 20 Then Element_Height=80
    If (Array[n].split(".")[1]) = "Probe" Then
Drawbox(255,255,75,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_He
ight),1)
    If (Array[n].split(".")[1]) = "Target" Then
Drawbox(255,128,75,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_He
ight),1)
    If (Array[n].split(".")[1]) = "Irrelevant"
    If (Array[n].split(".")[0])="1" Then
Drawbox(255,125,125,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_H
eight),1)
    If (Array[n].split(".")[0])="2" Then
Drawbox(255,100,100,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_H
eight),1)
    If (Array[n].split(".")[0])="3" Then
Drawbox(255,75,75,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_Hei
ght),1)
    If (Array[n].split(".")[0])="4" Then
Drawbox(255,50,50,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_Hei
ght),1)
    End If

    If Array.length > 20
    SetRotation (270)
    Text(Array[n],8,0,0,0,startpos+(Element_Width*n),(Element_Position+
70),0)
    SetRotation(0)
    Else
    Text(Array[n],10,0,0,0,startpos+(Element_Width*n)+
5,(Element_Position)+5,0)
    End If

    Else

    Drawbox(r,g,b,startpos+(Element_Width*n),(Element_Position),Element_Width,(Element_Hei
ght),1)
    Text(Array[n],10,0,0,0,startpos+(Element_Width*n)+5,(Element_Position)+5,0)
    End If
Next
End Function
'-----

```

Figure A.82. *Blitzmax Physiology CIT Stimuli Program – Functions (pg 12/13)*

```
' WAIT_MS (NUMBER OF MILLISECS TO WAIT)
```

```
-----  
FUNCTION
```

```
Function wait_ms(t:Long)
```

```
    t = MilliSecs()+t
```

```
    Repeat
```

```
        FlushKeys
```

```
        If KeyDown(KEY_E) Then t=9999
```

```
    Until MilliSecs()>=t
```

```
End Function
```

```
' This will wait for t millisecs
```

```
-----  
-----
```

*Figure A.83. Blitzmax Physiology CIT Stimuli Program – Functions (pg 13/13)*

Figure A.84. Blitzmax Physiology CIT Stimuli Program – Variable (pg 1/4)

```

'SHUFFLE AND REPEATS
'Trials
  Global Trial_Unit_Reps:Int=1          'Repeat the trials as a whole i.e.
  1.0.Probe,1.0.Target..[Irrelevants]..1.0.Probe,1.0.Target..[Irrelevants]
  Global Trial_Unit_Shuffle:Int=1      'Shuffle all trials within the CIT i.e.
  IITIPIIPTIII (trial_reps_all = 2 And (NoProbes = 1, NoTargets = 1, NoIrrelevant = 4) here
  For illustration)
    Global Trial_Element_Reps:Int=1    'Repeat the trials next to each other i.e.
    1.0.Probe,1.0.Probe,1.0.Target,1.0.Target...etc
    Global Trial_Element_Shuffle:Int=1 'Shuffle trial rep sections within the CIT e.g.
    IIPPIITIIIII (trial_reps_sec = 2 and (NoProbes = 1, NoTargets = 1, NoIrrelevant = 4) here
    for illustration)
  'CIT
    Global CIT_Unit_Reps:Int=1        'Repeat the CIT as a whole i.e.
    CIT1,CIT2,CIT3,CIT1,CIT2,CIT3
    Global CIT_Unit_Shuffle:Int=1     'Shuffle all CITs within the Epoch i.e.
    CIT2,CIT2,CIT3,CIT1,CIT3,CIT1 (CIT_Reps_all = 2 and NoCITs = 3 here for illustration)
    Global CIT_Element_Shuffle:Int=1 'Shuffle CIT rep sections within Epoch i.e.
    CIT1,CIT1,CIT3,CIT3,CIT2,CIT2 (CIT_Reps_sec = 2 and NoCITs = 3 here for illustration)
    Global CIT_Element_Reps:Int=1    'Repeat the CIT next to each other i.e.
    CIT1,CIT1,CIT2,CIT2,CIT3,CIT3
  'Condition_W
    Global Condition_W_Unit_Reps:Int=1 'Repeat the Condition_Ws as a whole i.e.
    Cond1,Cond2,Cond1,Cond2
    Global Condition_W_Unit_Shuffle:Int=0 'Shuffle the Condition_Ws within the
    Condition_B e.g. Cond2,Cond1,Cond1,Cond2 (Condition_W_Reps_all = 2 And NoCondition_Bs = 2
    here For illustration)
    Global Condition_W_Element_Reps:Int=1 'Repeat the Condition_Ws next to each other
    i.e. Cond1,Cond1,Cond2,Cond2
    Global Condition_W_Element_Shuffle:Int=0 'Shuffle the Condition_Ws Next To each
    other i.e. Cond2,Cond2,Cond1,Cond1 (Condition_W_Reps_Sec = 2 And NoCondition_Bs = 2 here
    For illustration)
  'Epoch
    Global Epoch_Unit_Reps:Int=1      'Repeat the Epochs as a whole i.e.
    Epoch1,Epoch2,Epoch1,Epoch2
    Global Epoch_Unit_Shuffle:Int=0   'Shuffle all Epochs within the epoch i.e.
    Epoch4,Epoch3,Epoch2,Epoch1 (Epoch_Reps_all = 1 and NoEpochs=5 here for illustration)
    Global Epoch_Element_Reps:Int=1   'Repeat the Epochs next to each other i.e.
    Epoch1,Epoch1,Epoch2,Epoch2
    Global Epoch_Element_Shuffle:Int=0 'Shuffle Epoch rep section within the epoch
    i.e. Epoch2,Epoch2,Epoch3,Epoch3,Epoch2,Epoch2 (Epoch_Reps_sec = 2 and NoEpochs=3 here for
    illustration)
  'Condition B
    Global Condition_B_Unit_Reps:Int=1 'Shouldn't ever need as Condition_B is
    purely time based!
    Global Condition_B_Unit_Shuffle:Int=0 'Shouldn't ever need as Condition_B is
    purely time based!
    Global Condition_B_Element_Reps:Int=1 'Shouldn't ever need as Condition_B is
    purely time based!
    Global Condition_B_Element_Shuffle:Int=0 'Shouldn't ever need as Condition_B is
    purely time based!
  'QUESTIONS
    Global Q_Loc_PreQ:String="n/a"
    Global Q_Loc:String="Middle"
    Global Q_Loc_PreImage:String="n/a"
    Global Q_Loc_Image:String="Top"
    Global Q_loc_PostImage:String="n/a"
    Global Question_Ar:String[9]

    'digitalout
    Global LPT1:Short= 52424
    'Short(digitalStream_ar[0])
    Global IOP:Int = LoadLibraryA("Configs/Output_Files/INPOUT32")
    'Load INPOUT library

```

Figure A.85. Blitzmax Physiology CIT Stimuli Program – Variable (pg 2/4)

```

'CALCULATION

'Global fadespeed:Float= 17/(FadePercent*ImageDuration)
Global CITSize:Int=(NoProbes+NoTargets+NoIrrelevants)
Global Buffer:String=""

'Total Trials
Global TotalNoTrials:Int=(AllTrial_Ar.length)
Global TotalNoCIT:Int=(AllCIT_Ar.length*AllCondition_B_Ar.length*AllEpoch_Ar.length)
Global TotalNoCondition_W:Int=(AllCondition_B_Ar.length*AllEpoch_Ar.length)
Global TotalNoEpoch:Int=(AllCondition_B_Ar.length*AllEpoch_Ar.length)
Global TotalNoCondition_B:Int=(NoCondition_B)

'FINAL ARRAYS
'Trial Arrays
Global Trial_Trial_Ar:String[TotalNoTrials]
Global CIT_Trial_Ar:String[TotalNoTrials]
Global condition_W_Trial_Ar:String[TotalNoTrials]
Global Epoch_Trial_Ar:String[TotalNoTrials]
Global Condition_B_Trial_Ar:String[TotalNoTrials]
Global ImageArray:TImage[TotalNoTrials]
Global MasterArray:String[TotalNoTrials,36]

'ERROR CHECK
Local zzz:Int=0
If (TotalNoCIT Mod TotalNoCondition_W)<>0 Then zzz=1
If zzz=1
    Print "Error! NoCondition_W doesn't equate to NoCITs"
End
End If

Global Im_Des_Ar:String[(NoProbes+NoIrrelevants+NoTargets)*NoCITs],2]
Global ImageDescription_Ar:String[TotalNoTrials]
Global ImageSizeAr:String[TotalNoTrials]

Global TempTrialArray:String[AllTrial_Ar.length]
Global TempCITArray:String[AllTrial_Ar.length]
Global TempEpochArray:String[AllTrial_Ar.length]
Global TempBetCondArray:String[AllTrial_Ar.length]

Global TrialRepNo:String=""
Global CITRepNo:String=""
Global WithCondRepNo:String=""
Global BetCondRepNo:String=""
Global EpochRepNo:String=""
Global Trigger:String=""

```

Figure A.86. *Blitzmax Physiology CIT Stimuli Program – Variable (pg 3/4)*

```

Global Out32:Byte(Port:Short, Value:Short) "win32" = GetProcAddress(IOP, "Out32")

Question_Ar[0]="The CCTV camera in the lab was masked; Do you recognize any of the
following as the; Method   used to cover the CCTV camera?"

Question_Ar[1]="Few have access to the highly secret lab that was broken into.; Do you
recognize any of the following as the; Lab   that was broken into?"

Question_Ar[2]="The hologram device was inside a padlocked case.; Do you recognize any
of the following as the; Tool   used to disable this lock?"

Question_Ar[3]="The stolen items were handed over at a predetermined location.; Do you
recognize any of the following as the; Location   as where the handover took place?"

Question_Ar[4]="The hacked computer required a secondary image password.; Do you
recognize any of the following as the; Image   password?"

Question_Ar[5]="We have the accomplice who organised the theft and received the device
in custody.; Do you recognize any of the following as the; Accomplice   in this crime?"

Question_Ar[6]="The review room next to the office displayed information about the
device.; Do you recognize any of the following as the; Information   on the screen?"

Question_Ar[7]="The office on the first floor was accessed using a keycard.; Do you
recognize any of the following as the specific; Office   accessed?"

Question_Ar[8]="The door to the lab was forced open.; Do you recognize any of the
following as the; Device   used to force the door?"

'@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
'ARRAYS
'Condition_B
Global Condition_B_Unit_Ar:String[NoCondition_B*Condition_B_Element_Reps]
Global Condition_B_Element_Ar:String[NoCondition_B]
Global
Condition_B_Ar:String[NoCondition_B*Condition_B_Element_Reps*Condition_B_Unit_Reps]
Global AllCondition_B_Ar:String[Condition_B_Ar.length]
'Epoch
Global Epoch_Unit_Ar:String[NoEpoch*Epoch_Element_Reps]
Global Epoch_Element_Ar:String[NoEpoch]
Global Epoch_Ar:String[NoEpoch*Epoch_Element_Reps*Epoch_Unit_Reps]
Global AllEpoch_Ar:String[Epoch_Ar.length*AllCondition_B_Ar.length]
'Condition_W
Global Condition_W_Unit_Ar:String[NoCondition_W*Condition_W_Element_Reps]
Global Condition_W_Element_Ar:String[NoCondition_W]
Global
Condition_W_Ar:String[NoCondition_W*Condition_W_Element_Reps*Condition_W_Unit_Reps]
Global
AllCondition_W_Ar:String[Condition_W_Ar.length*Epoch_Ar.length*Condition_B_Ar.length]
'CIT
Global CIT_Unit_Ar:String[NoCITs*CIT_Element_Reps]
Global CIT_Element_Ar:String[NoCITs]
Global CIT_Ar:String[NoCITs*CIT_Element_Reps*CIT_Unit_Reps]
Global AllCIT_Ar:String[CIT_Ar.length*AllEpoch_Ar.length]
'Trials
Global Trial_Unit_Ar:String[(NoProbes+NoTargets+NoIrrelevants)*Trial_Element_Reps]
Global Trial_Element_Ar:String[NoProbes+NoTargets+NoIrrelevants]
Global
Trial_Ar:String[(NoProbes+NoTargets+NoIrrelevants)*Trial_Element_Reps*Trial_Unit_Reps]
Global
AllTrial_Ar:String[Trial_Ar.length*CIT_Ar.length*Epoch_Ar.length*Condition_B_Ar.length]

```

Figure A.87. *Blitzmax Physiology CIT Stimuli Program – Variable (pg 4/4)*

```

SuperStrict

Include "RTCITVars.bmx"
'Include "RTCITPracticeVars.bmx"

Global RandISI:Int = 0

'#####
'#####
'#####
'BASIC SETUP
DisplaySize(xres,yres)
DisplaySet()
ParticipantNo()
Suspect()

'BUILD CIT STRUCTURE
BuildAllLevels()
TrialArrayStringEdit(CIT_Element_Ar,CITEdit_Ar)
BuildRTExperimentArray()
FillOutAr()
CSVToArray(Im_Des_Ar,"ImageDescription")
ImageDescription()
MakeMasterArray(totalnotrials,20)

'LOAD IMAGES
LoadImages(AllTrial_Ar,TotalNoTrials,ImageAddress)

'RUN EXPERIMENT
RunExperiment()

End
'#####
'#####
'#####

'RUN EXPERIMENT
-----
----- FUNCTION
Function RunExperiment()
    Local x:Int = 0
    Local Starttime:Long = MilliSecs()
    Local Endtime:Long = MilliSecs()
    Local TimeCheck:Long = MilliSecs()

    HideMouse()
    Cls; Text("Press Key to Start",40,0,0,0,Xres/2,Yres/2,1); Flip; WaitKey()
    Cls; Flip

    'SYNC MILLISECS TO ON THE SECOND TIME
    Repeat
        Until (MilliSecs() Mod 1000) = 0

    For Local c:Int = 0 To Epoch_ar.length-1

        'START EPOCH TEXT
        Cls; Text(("Start of Block " + (c+1)),50,255,255,255,xres/2,yres/2,1); Flip 1;
        wait_ms(500)

        For Local b:Int = 0 To CIT_Ar.length-1

```

Figure A.88. Blitzmax RTCIT Stimuli Program – Main (pg 1/14)



```

        Next

Cls; Text("End of Test",40,255,255,255,Xres/2,Yres/2,1); Flip 1; wait_ms(500)

End Function
'-----

'BUILD EACH LEVEL
'-----
FUNCTION
Function BuildAllLevels()
    BuildSingleArray(Trial_Element_Ar,CITSize,"Trials
",NoProbes,NoTargets,NoIrrelevants)
    BuildSingleArray(CIT_Element_Ar,NoCITs,"CIT ",NoProbes,NoTargets,NoIrrelevants)
    BuildSingleArray(Epoch_Element_Ar,NoEpoch,"Epoch
",NoProbes,NoTargets,NoIrrelevants)
End Function
'-----

'BUILD RT TRIAL ARRAY
'-----
Function BuildRTExperimentArray:String[]()

    Local d:Int=0
    Local q:Int=0
    Local e:Int=0
    Local f:Int=0
    Local g:Int=0
    Local o:Int=0

    ShuffleRepeats(Epoch_Ar,Epoch_Element_Ar,Epoch_Unit_Ar,Epoch_Element_Shuffle,Epoch_Unit_Shuffle,Epoch_Element_Reps,Epoch_Unit_Reps)
    For Local u:Int=0 To Epoch_Ar.length-1
        AllEpoch_Ar[e] = Epoch_Ar[u]
        e=e+1

        ShuffleRepeats(CIT_Ar,CIT_Element_Ar,CIT_Unit_Ar,CIT_Element_Shuffle,CIT_Unit_Shuffle,CIT_Element_Reps,CIT_Unit_Reps)
        For Local w:Int=0 To CIT_Ar.length-1
            AllCIT_Ar[d] = CIT_Ar[w]
            d=d+1

            ShuffleRepeats(Trial_Ar,Trial_Element_Ar,Trial_Unit_Ar,Trial_Element_Shuffle,Trial_Unit_Shuffle,Trial_Element_Reps,Trial_Unit_Reps)
            For Local v:Int= 0 To Trial_Ar.length -1
                AllTrial_Ar[q] = String(CIT_Ar[w].split(" ")[1]) + "." + Trial_Ar[v]
                q=q+1
            Next
        Next

        ShuffleStringArray(AllTrial_Ar,(((NoProbes+NoTargets+NoIrrelevants)*NoCITs)*(u+1)),(((NoProbes+NoTargets+NoIrrelevants)*NoCITs)*u))

    Next
End Function

```

Figure A.89. Blitzmax RTCIT Stimuli Program – Main (pg 2/14)

```

For Local a:Int =0 To Trial_Ar.length-1
    FlushKeys()

    'PRESENT IMAGE
    DrawTrial((ImageArray[x]), MasterArray[x,9])
    Starttime = MilliSecs()

    'CHECK RESPONSE
    RTCITStimuli(x)

    'WAIT FOR IMAGEDURATION
    Local durationReached:Int = 0
    Repeat
        endtime = MilliSecs()
        timecheck = (endtime - starttime)
        If timecheck => imageduration Then durationReached = 1
    Until durationReached = 1

    'WAIT ISI
    If TestingCondition = "Together"
        ISI_Together()
    Else TestingCondition = "Seperately"
        ISI_Seperate()
    EndIf

    'Output Trial

    Outfile(MasterArray[x,0],MasterArray[x,1],MasterArray[x,2],MasterArray[x,3],MasterArray[x,4],MasterArray[x,5],MasterArray[x,6],MasterArray[x,7],MasterArray[x,8],MasterArray[x,9],MasterArray[x,10],String(MilliSecs()),MasterArray[x,12],(InterStimuliInterval-RandISI),reactiontime,correct,reactiontime_B,correct_B,TestingCondition,SuspectNumber)

    '_____Experiment_____Stage_____Stimuli_Set_____TimeStamp_____Participant_____ImageDuration_____Epoch_____CITNo_____Item_____ItemString_____TrialNumber_____TrialTime_____ImageDescription_____ISI_____RT_A_____Correct_A_____RT_B_____Correct_B_____Testing_____Suspect_____

    'NEXT TRIAL
    x=x+1

    If KeyHit(Key_ESCAPE) Then a=999; b=999; c=999
Next
ResetArray(TempTrialArray)

Next
ResetArray(TempCITArray)

'END EPOCH TEXT
Cls; Text(("End of Block "+(c+1)),50,255,255,255,xres/2,yres/2,1); Flip 1;
wait_ms(500)

If Left(Participant,1)="p"
    If c = 1
        c = c + 997
    End If
End If

If ((c+1) Mod 3)=0
    For Local j:Int = 5 To 1 Step -1
        Cls; Text(("5 Second Break: "+j),50,255,255,255,xres/2,yres/2,1); Flip
1; Wait_ms(1000)
    Next
EndIf

```

Figure A.90. Blitzmax RTCIT Stimuli Program – Main (pg 3/14)

```

'-----
-----

Function ShuffleRepeats:String[]
(Ar:String[],Element_Ar:String[],Unit_Ar:String[],Element_Shuffle:Int,Unit_Shuffle:Int,Element_Reps:Int,Unit_Reps:Int)

    If Element_Shuffle = 1 Then ShuffleStringArray(Element_Ar,Element_Ar.length-1,0)
    RepeatElements((Element_Ar),(Unit_Ar),(Element_Reps))
    If Unit_Shuffle = 1 Then ShuffleStringArray(Unit_Ar,Unit_Ar.length-1,0)
    RepeatUnits((Unit_Ar),(Ar),(Unit_Reps))
    Return Ar

End Function
'-----
-----

'SHUFFLE ARRAY
-----
----- FUNCTION

Function ShuffleStringArray:String[](Array:String[],Length:Int,Start:Int)
    Local m1:Int=0
    Local m2:Int=0
    Local element1:String=0
    Local element2:String=0
    Local a:Int=0

Repeat
    a=0

    For Local i:Int = 0 To 10000
        m1 = Rand(Start,Length-1)
        m2 = Rand(Start,Length-1)
        element1 = Array[m1]
        element2 = Array[m2]
        Array[m1] = element2
        Array[m2] = element1
    Next

    If Array[0].Contains("Probe")
        a=1
    End If

    For Local i:Int=0 To Array.length-2
        If Array[i].Contains("Target")
            If Array[i+1].Contains("Probe") Then a=1
        EndIf
        If Array[i].Contains("Probe")
            If Array[i+1].Contains("Probe") Then a=1
        End If
    Next

Until a=0

Return Array

End Function
'-----
-----

```

Figure A.91. Blitzmax RTCIT Stimuli Program – Main (pg 4/14)

```

'REPEAT ELEMENTS IN ARRAY
-----
FUNCTION
Function RepeatElements:String[](Array:String[],NewArray:String[],Reps:Int)
Local w:Int=0
w=0
For Local i:Int = 0 To Array.length-1
    For Local j:Int =0 To Reps-1
        NewArray[w]=Array[i]
        w=w+1
    Next
Next
Return NewArray
End Function
'
-----

'FILL OUT ARRAYS
-----
FUNCTION
Function FillOutAr()
    FillArrayOut(Epoch_Trial_Ar,AllEpoch_Ar)
    FillArrayOut(CIT_Trial_Ar,AllCIT_Ar)
End Function
'
-----

'IMAGE DESCRIPTION ARRAY
-----
FUNCTION
Function ImageDescription()
For Local j:Int=0 To (Im_Des_Ar.length/2)-1
    For Local i:Int=0 To TotalNoTrials-1
        If AllTrial_Ar[i] = Im_Des_Ar[j,0] Then ImageDescription_Ar[i] = Im_Des_Ar[j,1]
    Next
Next
End Function
'
-----

'MAKE MASTER ARRAYS
-----
FUNCTION
Function MakeMasterArray(Length:Int,Width:Int)

For Local l:Int = 0 To Length-1
    MasterArray[l,0]= Experiment

    If Left(Participant,1)="p"
        MasterArray[l,1]= "Practice"
    Else
        MasterArray[l,1]= "Main"
    End If

    MasterArray[l,2]= Stimuli_Set
    MasterArray[l,3]= TimeStamp
    MasterArray[l,4]= Participant
    MasterArray[l,5]= ImageDuration
    MasterArray[l,6]= Epoch_Trial_Ar[l]
    MasterArray[l,7]= AllTrial_Ar[l].split(".")[0]
    MasterArray[l,8]= AllTrial_Ar[l].split(".")[2]

```

Figure A.92. Blitzmax RTCIT Stimuli Program – Main (pg 5/14)

```

MasterArray[1,9]= AllTrial_Ar[1]
MasterArray[1,10]= (1+1)
MasterArray[1,11]= MilliSecs()
MasterArray[1,12]= AllTrial_Ar[1]
MasterArray[1,13]= ImageDescription_Ar[1]
MasterArray[1,14]= InterStimuliInterval
MasterArray[1,18]= TestingCondition
MasterArray[1,19]= SuspectNumber

Next
End Function
'-----
'-----

'Reaction Time CIT Stimuli
'-----
'-----

Function RTCITStimuli(x:Int)
    Local startmilliseconds:Long = 0
    Local endmilliseconds:Long = 0
    Local currentmilliseconds:Long = 0
    Local exitloop:Int = 0
    Local responseA:String = ""
    Local responseB:String = ""
    Local responsemade_A:Int=0
    Local responsemade_B:Int=0
    Local ResponseTest:Int=999
    reactiontime = imageduration
    reactiontime_B = imageduration

    startmilliseconds = MilliSecs()

    Repeat

        If responsemade_A = 0 'If there's been no response yet from A then allow key
checking
            If KeyHit(KEY_RIGHT)
                responseA = "R"
            ElseIf KeyHit(KEY_LEFT)
                responseA = "L"
            EndIf

            If responseA <> ""
                responsemade_A = 1
                endmilliseconds = MilliSecs()
                reactiontime = endmilliseconds - startmilliseconds 'Record the time RT_A
happened

                If (responseA="R") And (MasterArray[x,8] = "Target") Then correct=0
                If (responseA="L") And (MasterArray[x,8] = "Target") Then correct=1
                If (responseA="R") And (MasterArray[x,8] = "Irrelevant") Then correct=1
                If (responseA="L") And (MasterArray[x,8] = "Irrelevant") Then correct=0
                If (responseA="R") And (MasterArray[x,8] = "Probe") Then correct=1
                If (responseA="L") And (MasterArray[x,8] = "Probe") Then correct=0

            EndIf
        End If

        If responsemade_B = 0 'If there's been no response yet from B then allow key
checking
            If KeyHit(KEY_C)
                responseB = "C"
            EndIf
        End If
    Until exitloop = 1
End Function

```

Figure A.93. Blitzmax RTCIT Stimuli Program – Main (pg 6/14)

```

ElseIf KeyHit(KEY_Z)
    responseB = "Z"
EndIf

If responseB <> ""
    responsemade_B = 1
    endmilliseconds = MilliSecs()
    reactiontime_B = endmilliseconds - startmilliseconds 'Record the time RT_B
happened

    If (responseB="C") And (MasterArray[x,8] = "Target") Then correct_B=0
    If (responseB="Z") And (MasterArray[x,8] = "Target") Then correct_B=1
    If (responseB="C") And (MasterArray[x,8] = "Irrelevant") Then correct_B=1
    If (responseB="Z") And (MasterArray[x,8] = "Irrelevant") Then correct_B=0
    If (responseB="C") And (MasterArray[x,8] = "Probe") Then correct_B=1
    If (responseB="Z") And (MasterArray[x,8] = "Probe") Then correct_B=0

End If
End If

If responsemade_A = 1
    If responsemade_B = 1
        exitloop = 1
    EndIf
EndIf

If Exitloop = 0
    currentmilliseconds = MilliSecs()
    If (currentmilliseconds - startmilliseconds) => imageduration
        ResponseTest = responsemade_A + responsemade_B
        If responsemade_A = 1
            correct_B = 2
            exitloop = 1
        EndIf
        If responsemade_B = 1
            correct = 2
            exitloop = 1
        End If
        If ResponseTest = 0
            correct_B = 2
            correct = 2
            exitloop = 1
        EndIf
    End If
End If

Until exitloop = 1

FlushKeys()

End Function
'-----
'DRAW STIMULI
'-----
FUNCTION
Function DrawTrial(Image:TImage, ImageLocation:String)
    Cls;
    ScaleImage(Image,ImageScale)
    DrawImage(Image,(xres/2),(yres/2))
    SetScale(1,1)
    Flip

```

Figure A.94. Blitzmax RTCIT Stimuli Program – Main (pg 7/14)

```

End Function
'-----
'-----

'WAIT ISI
'-----
'----- FUNCTION
Function ISI_Together()

    Local r:Int = Rand(1,3)
    If r = 1 Then RandISI = 500
    If r = 2 Then RandISI = 250
    If r = 3 Then randISI = 0

    Cls
    '-----Both Correct-----
    If correct = 1
        If correct_B = 1
            Cls
        EndIf
    EndIf

    '-----Incorrect-----
    If Left(Participant,1) = "p"
        If correct = 0 Then Text("Incorrect",50,0,0,0,3*xres/4,yres/2,1)
        If correct_B = 0 Then Text("Incorrect",50,0,0,0,xres/4,yres/2,1)
    EndIf

    '-----Too slow-----
    If correct = 2 Then Text("Too Slow",50,0,0,0,3*xres/4,yres/2,1)
    If correct_B = 2 Then Text("Too Slow",50,0,0,0,xres/4,yres/2,1)

    Flip 1
    wait_ms(InterStimuliInterval-RandISI)

EndFunction
'-----
'-----

'WAIT ISI
'-----
'----- FUNCTION
Function ISI_Seperate()

    Local r:Int = Rand(1,3)
    If r = 1 Then RandISI = 500
    If r = 2 Then RandISI = 250
    If r = 3 Then randISI = 0

    Cls
    '-----Both Correct-----
    If correct = 1
        Cls
    EndIf

    '-----Incorrect-----
    If Left(Participant,1) = "p"
        If correct = 0 Then Text("Incorrect",50,0,0,0,xres/2,yres/2,1)
    EndIf

    '-----Too slow-----
    If correct = 2 Then Text("Too Slow",50,0,0,0,xres/2,yres/2,1)

```

Figure A.95. *Blitzmax RTCIT Stimuli Program – Main (pg 8/14)*

```

Flip 1
wait_ms(InterStimuliInterval-RandISI)

EndFunction
'-----

'OUTFILE
'-----
FUNCTION
Function
Outfile(Experiment:String,Stage:String,Stimuli_Set:String,TimeStamp:String,Participant:String,
ImageDuration:String,Epoch:String,CITNo:String,Item:String,ItemString:String,TrialNumber:
String,TrialTime:String,ImageDescription:String,ISI:String,RT:Int,correct:Int,RT_B:Int,
Correct_B:Int,Testing:String,Suspect:String)
    Local Name:String = ""
    Local filename:String = "RT Data/" + Participant + "(" + Experiment + ").csv"
    If FileType(filename) = 0 Then CreateFile(filename)
    Local Stream:TStream = OpenStream(filename)
    SeekStream(stream, stream.Size())
    If stream.Size() = 0 Then WriteLine stream,
"Experiment,Stage,Stimuli_Set,TimeStamp,Participant,ImageDuration,Epoch,CITNo,Item,ItemString,
TrialNumber,TrialTime,ImageDescription,ISI,RT,Correct,RT_B,Correct_B,Testing,Suspect"
    WriteLine(stream,
Experiment+", "+Stage+", "+Stimuli_Set+", "+TimeStamp+", "+Participant+", "+ImageDuration+", "+E
poch+", "+CITNo+", "+Item+", "+ItemString+", "+TrialNumber+", "+TrialTime+", "+ImageDescription+",
"+ISI+", "+RT+", "+correct+", "+RT_B+", "+Correct_B+", "+Testing+", "+Suspect)
    CloseStream(stream)
EndFunction
'-----

'BUILD SINGLE CIT
FUNCTION-----
FUNCTION
Function BuildSingleArray:String[]
(Array:String[],Number:Int,Label:String,NoProbes:Int,NoTargets:Int,NoIrrelevants:Int)
    If Label <> "Trials "
        For Local y:Int=0 To Array.length-1
            For Local Xn:Int=0 To Number-1

```

Figure A.96. Blitzmax RTCIT Stimuli Program – Main (pg 9/14)



```

        Array[y] = Label + (Xn+1)
        y=y+1
    Next
Next
Else If Label = "Trials "
    For Local x:Int=0 To Array.length-1
        For Local PN:Int=0 To NoProbes-1
            Array[x] = (PN)+".Probe"
            x=x+1
        Next
        For Local TN:Int=0 To NoTargets-1
            Array[x] = (TN)+".Target"
            x=x+1
        Next
        For Local IN:Int=0 To NoIrrelevants-1
            Array[x] = (IN+1)+".Irrelevant"
            x=x+1
        Next
    Next
End If
Return Array
End Function
'-----
'-----

'READING IN CSV TO ARRAY
'-----FUNCTION

Function CSVToArray:String[,] (Array:String[,],Filename:String)

    Local Textstream:TStream = ReadStream(ImageAddress+Filename+".csv")
    Local LinestoRead:Int = Array.length
    Local TextString:String = ""

    For Local i:Int = 0 To (array.length/2) -1
        TextString = ReadLine(Textstream)
        Array[i,0] = TextString.Split(",")[0]
        Array[i,1] = TextString.Split(",")[1]
    Next
    Eof(Textstream)
    Return Array
End Function

'-----
'-----

'GRAPHICS
'+++++
'+++++

'DISPLAYSIZE-----FUNCTION
'Get system resolution
Function DisplaySize(Xres:Int Var, Yres:Int Var)
    Extern "Win32"
    Function GetSystemMetrics:Int(Axis:Int)
    End Extern
    xRes:Int=GetSystemMetrics(0)      'x resolution of the screen from the Win32
command
    yRes:Int=GetSystemMetrics(1)      'y resolution of the screen from the Win32
command
End Function

```

Figure A.97. Blitzmax RTCIT Stimuli Program – Main (pg 10/14)

```

'-----
'-----

'DISPLAY
SETTINGS-----
----- FUNCTION
'Setting graphics resolution
Function DisplaySet()
    SetGraphicsDriver GLMax2DDriver()
    Graphics Xres,Yres,WindowMode
    SetClsColor(Background_R,Background_G,Background_B)
    SetMaskColor(Background_R,Background_G,Background_B)
    AutoMidHandle(1)
    SetBlend Alphablend
    Cls
EndFunction
'-----
'-----

'+++++
'+++++

'FILL OUT ARRAY
-----
'Fill out NewArray with Array in a balanced manner
Function FillArrayOut:String[] (NewArray:String[],Array:String[])
    Local x:Int = 0
    For Local j:Int = 0 To Array.length-1
        For Local i:Int=0 To (NewArray.length/Array.length)-1
            NewArray[x] = Array[j]
            x=x+1
        Next
    Next
    Return NewArray
End Function
'-----
'-----

'GET TEXT INPUT FROM USER
-----FUNCTION
Function gInput:String(x:Int,y:Int,prompt:String = "?")
    Local m:String=""
    While 1
        Cls
        SetColor(255,255,255)
        DrawText prompt$+m$,x,y
        Local nextKey:Int = GetChar()
        If nextKey
            If nextKey = KEY_ENTER
                Return m
            Else If nextKey = KEY_BACKSPACE
                'l = Len(m$)
                m = m[..Len(m)-1]
            Else
                m$ = m$ + Chr$(nextKey)
            EndIf
        EndIf
        Flip True
    Wend
End Function
'-----
'-----

```

Figure A.98. Blitzmax RTCIT Stimuli Program – Main (pg 11/14)

```

'LOAD IMAGES
-----
----- FUNCTION
Function LoadImages:String[] (Array:String[], NoImages:Int, ImageAddress:String)

    Local LoadingIn:String="Loading"
    Local image_ar:String[ImageArray.length]
    Local pos:Int = 0
    Local NotUnique:Int = 0

    For Local v:Int=0 To NoImages-1
        For Local i:Int = 0 To NoImages-1
            If ImageAddress + Array[v] + ".png" = image_ar[i] Then NotUnique = 1; Pos = i
        Next

        If NotUnique = 0
            image_ar[v] = ImageAddress + Array[v] + ".png"
            ImageArray[v] = resizeimage(LoadImage(ImageAddress + Array[v] +
".png"),xres,yres,IMAGESCALE)
            LoadingIn = LoadingIn + "."
            Cls; DrawText>LoadingIn,10,10); Flip 1

        Else
            imageArray[v] = imageArray[pos]
        EndIf

    Next
End Function
'-----

'resize images
'-----
-----
Function ResizeImage:TImage(image:TImage,width:Int,height:Int, imagescale:Float)
    Local pix:TPixmap=LockImage(image)
    Local ScaleToScreen:Float = 0
    Local Iheight:Int
    Iheight = ImageHeight(image)
    ScaleToScreen = Float(height)/Iheight
    pix=ResizePixmap(pix,((Width*imagescale))*ScaleToScreen,(height*imagescale)*ScaleToScreen)
    UnlockImage(image)
    Return LoadImage(pix)
End Function
'-----

'PARTICIPANT
NUMBER-----
-----FUNCTION
Function ParticipantNo()
    Repeat
        Cls
        Participant= ginput(20,20,"Pair Number: ")
    Until (Participant.length <>"")
    If Left(Participant,1)="p" Then Stage = "Practice"
End Function
'-----

```

Figure A.99. Blitzmax RTCIT Stimuli Program – Main (pg 12/14)

```

'PAIRED
TESTING-----FUNCTION
Function Suspect()
    Repeat
        Cls
        TestingCondition= ginput(20,20,"Are you taking the test at the same time as your
partner? (y or n): ")
    Until (TestingCondition.length <>"")

    If TestingCondition = "y"
        TestingCondition = "Together"
    Else
        TestingCondition = "Seperately"
    EndIf

    If TestingCondition = "Seperately"
        Repeat
            Cls
            SuspectNumber= ginput(20,20,"Please enter your suspect letter (a or b): ")
        Until (SuspectNumber.length <>"")
    EndIf

End Function
'-----

'REPEAT UNITS IN ARRAY
-----FUNCTION
Function RepeatUnits:String[] (Array:String[],NewArray:String[],Reps:Int)
    Local w:Int=0
    w=0
    For Local i:Int = 0 To Reps-1
        For Local j:Int =0 To Array.length-1
            NewArray[w]=Array[j]
            w=w+1
        Next
    Next
    Return NewArray
End Function
'-----

'RESET AN
ARRAY-----
Function ResetArray:String[] (Array:String[])
    For Local i:Int =0 To Array.length-1
        Array[i] = ""
    Next
End Function
'-----

'SCALE STIMULI
-----FUNCTION
Function ScaleImage(Image:TImage,ImageScale:Float)
    Local x:Float = ImageHeight(Image)
    Local y:Float = ImageWidth(Image)
    SetScale((xres/(y/ImageScale)),(yres/(x/ImageScale)))
End Function

```

Figure A.100. Blitzmax RTCIT Stimuli Program – Main (pg 13/14)

```

' TEXT SETUP
' ++++++
+++++

' TEXT
FUNCTION-----
----- FUNCTION
    'Draw Text to screen
    Function Text(Text:String,SizeFont:Int,R:Int,G:Int,B:Int,Xpos:Int,Ypos:Int,Centre:Int)
        If SizeFont =0 Then SizeFont = DefaultFontSize
        Local FontB:TImageFont=LoadImageFont("C:\WINDOWS\Fonts
\"+BasicFontType+".ttf",SizeFont)
        SetImageFont FontB
        SetColor(R,G,B)
        SetBlend ALPHABLEND

        If text.contains(";")=0

            If Centre = 1 Then DrawText(text,Xpos-(TextWidth(text)/2),Ypos-sizefont/2)
            If Centre = 0 Then DrawText(text,Xpos,Ypos)

        Else If text.contains(";")>0
            If Centre = 1
                DrawText((text.split(";")[0]),Xpos-(TextWidth(text.split(";")
[0])/2),Ypos-(sizefont))
                DrawText((text.split(";")[1]),Xpos-(TextWidth(text.split(";")
[1])/2),Ypos)
                DrawText((text.split(";")[2]),Xpos-(TextWidth(text.split(";")
[2])/2),Ypos+(sizefont))
            End If

            If Centre = 0
                DrawText((text.split(";")[0]),Xpos,Ypos-(sizefont))
                DrawText((text.split(";")[1]),Xpos,Ypos)
                DrawText((text.split(";")[2]),Xpos,Ypos+(sizefont))
            End If
        End If

        SetColor(255,255,255)
        SetScale(1,1)
    End Function
'-----
-----

' ++++++
+++++

' TRIAL ITEM LIST EDIT
-----
----- FUNCTION
Function TrialArrayStringEdit:String[](Array:String[],Edit_Ar:String[])
    For Local i:Int =0 To Array.length-1
        Array[i] = Array[i].split(" ")[0] + " " + Edit_Ar[i]
    Next
End Function
'-----

' WAIT_MS (NUMBER OF MILLISECS TO WAIT)
-----
FUNCTION
Function wait_ms(t:Int);
    Local endTime:Long=MilliSecs()+t
    Local dummy:String=""
    Repeat
        If KeyDown(KEY_ESCAPE) Then dummy="1"
    Until MilliSecs()>=endTime;
End Function
' This will wait for t millisecs
'-----

```

Figure A.101. Blitzmax RTCIT Stimuli Program – Main (pg 14/14)

Figure A.102. Blitzmax RTCIT Stimuli Program – Variable (pg 1/4)

```

Condition_B_Ar:String[NoCondition_B*Condition_B_Element_Reps*Condition_B_Unit_Reps]
Global AllCondition_B_Ar:String[Condition_B_Ar.length]
'Epoch
Global Epoch_Unit_Ar:String[NoEpoch*Epoch_Element_Reps]
Global Epoch_Element_Ar:String[NoEpoch]
Global Epoch_Ar:String[NoEpoch*Epoch_Element_Reps*Epoch_Unit_Reps]
Global AllEpoch_Ar:String[Epoch_Ar.length*AllCondition_B_Ar.length]
'Condition_W
Global Condition_W_Unit_Ar:String[NoCondition_W*Condition_W_Element_Reps]
Global Condition_W_Element_Ar:String[NoCondition_W]
Global
Condition_W_Ar:String[NoCondition_W*Condition_W_Element_Reps*Condition_W_Unit_Reps]
Global
AllCondition_W_Ar:String[Condition_W_Ar.length*Epoch_Ar.length*Condition_B_Ar.length]
'CIT
Global CIT_Unit_Ar:String[NoCITs*CIT_Element_Reps]
Global CIT_Element_Ar:String[NoCITs]
Global CIT_Ar:String[NoCITs*CIT_Element_Reps*CIT_Unit_Reps]
Global AllCIT_Ar:String[CIT_Ar.length*AllEpoch_Ar.length]
'Trials
Global Trial_Unit_Ar:String[(NoProbes+NoTargets+NoIrrelevants)*Trial_Element_Reps]
Global Trial_Element_Ar:String[NoProbes+NoTargets+NoIrrelevants]
Global
Trial_Ar:String[(NoProbes+NoTargets+NoIrrelevants)*Trial_Element_Reps*Trial_Unit_Reps]
Global
AllTrial_Ar:String[Trial_Ar.length*CIT_Ar.length*Epoch_Ar.length*Condition_B_Ar.length]

'CALCULATION

Global fadespeed:Float= 17/(FadePercent*ImageDuration)
Global CITSize:Int=(NoProbes+NoTargets+NoIrrelevants)
Global Buffer:String=""

'Total Trials
Global TotalNoTrials:Int=(AllTrial_Ar.length)
Global TotalNoCIT:Int=(AllCIT_Ar.length*AllCondition_B_Ar.length*AllEpoch_Ar.length)
Global TotalNoCondition_W:Int=(AllCondition_B_Ar.length*AllEpoch_Ar.length)
Global TotalNoEpoch:Int=(AllCondition_B_Ar.length*AllEpoch_Ar.length)
Global TotalNoCondition_B:Int=(NoCondition_B)

'FINAL ARRAYS
'Trial Arrays
Global Trial_Trial_Ar:String[TotalNoTrials]
Global CIT_Trial_Ar:String[TotalNoTrials]
Global condition_W_Trial_Ar:String[TotalNoTrials]
Global Epoch_Trial_Ar:String[TotalNoTrials]
Global Condition_B_Trial_Ar:String[TotalNoTrials]
Global ImageArray:TImage[TotalNoTrials]
Global MasterArray:String[TotalNoTrials,36]

'ERROR CHECK
Local zzz:Int=0
If (TotalNoCIT Mod TotalNoCondition_W)<>0 Then zzz=1
If zzz=1
    Print "Error! NoCondition_W doesn't equate to NoCITs"
End
End If

Global Im_Des_Ar:String[((NoProbes+NoIrrelevants+NoTargets)*NoCITs),2]
Global ImageDescription_Ar:String[TotalNoTrials]
Global ImageSizeAr:String[TotalNoTrials]

Global TempTrialArray:String[AllTrial_Ar.length]

```

Figure A.103. Blitzmax RTCIT Stimuli Program – Variable (pg 2/4)

[illegible]

Figure A.104. Blitzmax RTCIT Stimuli Program – Variable (pg 3/4)



```
Global TempCITArray:String[AllTrial_Ar.length]
Global TempEpochArray:String[AllTrial_Ar.length]
Global TempBetCondArray:String[AllTrial_Ar.length]

Global TrialRepNo:String=""
Global CITRepNo:String=""
Global WithCondRepNo:String=""
Global BetCondRepNo:String=""
Global EpochRepNo:String=""
Global Trigger:String=""

REACTION TIME
Global correct:Int = 999
Global reactiontime:Long = 0
Global correct_B:Int = 999
Global reactiontime_B:Long = 0
Global TestingCondition:String=""
Global SuspectNumber:String="A&B"
```

*Figure A.105. Blitzmax RTCIT Stimuli Program – Variable (pg 4/4)*

## Unity Script

```

...4 - VR Condition Program (VR CIT)\VR CIT\Main VR CIT.cs 1
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;
using System.IO.Ports;
using System.IO;
using System;
using UnityEngine.UI;

public class Main : MonoBehaviour {

    // Note for Ports to work you need to change the Api Compatibility Level  P
    // fro .NET 2.0
    private SerialPort Stream;
    private int NextStimulusNumber = -1;
    public bool BiopacOutput = false;
    public Color AmbientColor; // = new Color(0.8F, 0.8F, 0.8F);

    public float ISI1 = 0;
    public float ISI2 = 0;
    public float StimulusDuration = 0;
    public float QuestionDuration = 0;

    //public List<string> Trials;
    private List<string> Trials = new List<string>(); //https://forum.unity.com/  P
    //threads/cant-add-child-transforms-to-private-list-but-public-list-works-  P
    //fine.447558/
    private int NumberOfTrials = -1;
    public GameObject MessagesCanvas;
    public Text MessageText;
    public List<GameObject> StimulusMesh; // the stimulus meshes

    private IEnumerator RunExperiment()
    {
        if (BiopacOutput) Stream = new SerialPort("COM4", 115200);
        if (BiopacOutput) Stream.Open();

        MessageText.text = "";
        StimulusMesh[0].SetActive(true); // show baseline lab mesh

        // Wait for the Space key to be pressed
        do
        {
            yield return null;
        } while (!Input.GetKeyDown(KeyCode.Space));

        yield return new WaitForSeconds(1.0f); // wait for 1 second for comfort

        for (int i = 0; i < NumberOfTrials; i++)
        {
            StimulusMesh[0].SetActive(true); // show baseline lab mesh

            if (i==0 || i == 4 || i == 8 || i == 12 || i == 16 || i == 20 || i ==  P
                24 || i == 28 )

```

Figure A.106. Unity Script for VR Project – Main (pg 1/3)

```

...4 - VR Condition Program (VR CIT)\VR CIT\Main VR CIT.cs 2
{
    //StimulusMesh[0].SetActive(true); // show baseline lab mesh
    MessageText.text = Trials[i].Split(',')[23];
    yield return new WaitForSeconds(QuestionDuration);
    MessageText.text = "";
}

yield return new WaitForSeconds(ISI1);
// SEND TRIGGER?

if (BiopacOutput) { Stream.Write(Convert.ToChar(101).ToString());
    Stream.BaseStream.Flush(); }

if (Trials[i].Split(',')[26].Split('.')[2] == "Probe") Debug.Log
    ("eda_Probe");
if (Trials[i].Split(',')[26].Split('.')[2] == "Irrelevant") Debug.Log
    ("eda_Irrelevant");

if (Trials[i].Split(',')[26] == "1.0.Probe") NextStimulusNumber = 5;
if (Trials[i].Split(',')[26] == "2.0.Probe") NextStimulusNumber = 1;
if (Trials[i].Split(',')[26] == "3.0.Probe") NextStimulusNumber = 2;
if (Trials[i].Split(',')[26] == "4.0.Probe") NextStimulusNumber = 3;
if (Trials[i].Split(',')[26] == "4.1.Irrelevant") NextStimulusNumber =
    4;
if (Trials[i].Split(',')[26] == "4.2.Irrelevant") NextStimulusNumber =
    5;
if (Trials[i].Split(',')[26] == "4.3.Irrelevant") NextStimulusNumber =
    6;
if (Trials[i].Split(',')[26] == "4.4.Irrelevant") NextStimulusNumber =
    7;

StimulusMesh[0].SetActive(false); // remove baseline lab mesh
StimulusMesh[NextStimulusNumber].SetActive(true);
yield return new WaitForSeconds(StimulusDuration);
StimulusMesh[NextStimulusNumber].SetActive(false);
StimulusMesh[0].SetActive(true); // show baseline lab mesh
yield return new WaitForSeconds(ISI2);

}

if (BiopacOutput) Stream.Close();

MessageText.text = "End of Block";
yield return new WaitForSeconds(3.0f);

yield return null;
}

// Use this for initialization
void Start()
{
    // https://www.youtube.com/watch?v=mAeTRCT0qZg
    // https://www.codeproject.com/Questions/384247/How-to-read-from-csv-file-
    using-csharp-net

```

Figure A.107. Unity Script for VR Project – Main (pg 2/3)

---

...4 - VR Condition Program (VR CIT)\VR CIT\Main VR CIT.cs

3

```
RenderSettings.ambientMode = UnityEngine.Rendering.AmbientMode.Flat;
RenderSettings.ambientLight = AmbientColor;

StreamReader sr = new StreamReader("InputTest.csv");
String TextLine = "";
NumberOfTrials = 0;

TextLine = sr.ReadLine();

Debug.Log("reading file");
while (!sr.EndOfStream)
{
    NumberOfTrials++;
    Trials.Add(sr.ReadLine());
}
sr.Close();

Debug.Log("calling RunExperiment");
StartCoroutine(RunExperiment());
}

// Update is called once per frame
void Update()
{
}

}
```

*Figure A.108. Unity Script for VR Project – Main (pg 3/3)*

```

...IT)\4 - VR Condition Program (VR CIT)\VR CIT\Preview.cs 1
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;
using System.IO.Ports;
using System.IO;
using System;
using UnityEngine.UI;

public class Main : MonoBehaviour {

    // Note for Ports to work you need to change the Api Compatibility Level ➤
    fro .NET 2.0
    public Color AmbientColor;// = new Color(0.8F, 0.8F, 0.8F);
    private int[]SceneOrder={1,2,3,4,5,6,7}; // remember 0 is the LAB
    public float StimulusDuration = 0;

    public GameObject MessagesCanvas;
    public Text MessageText;
    public List<GameObject> StimulusMesh; // the stimulus meshes

    //https://stackoverflow.com/questions/36702548/shuffle-array-in-unity
    //https://answers.unity.com/questions/16531/randomizing-arrays.html
    //for shuffle number from array
    public static void ShuffleArray<T>(T[] arr) {
        for (int i = arr.Length - 1; i > 0; i--) {
            int r = UnityEngine.Random.Range(0, i);
            T tmp = arr[i];
            arr[i] = arr[r];
            arr[r] = tmp;
        }
    }

    private IEnumerator RunExperiment()
    {
        // Wait for the Space key to be pressed
        do
        {
            yield return null;
        } while (!Input.GetKeyDown(KeyCode.Space));

        for (int i = 0; i < 7; i++)
        {
            if (i == 0){
                StimulusMesh[0].SetActive(false);
                StimulusMesh[SceneOrder[i]].SetActive(true);
            }
            else
            {
                StimulusMesh[SceneOrder[i-1]].SetActive(false);
                StimulusMesh[SceneOrder[i]].SetActive(true);
            }
        }
    }
}

```

Figure A.109. Unity Script for VR Project – Preview (pg 1/2)

```
...IT)\4 - VR Condition Program (VR CIT)\VR CIT\Preview.cs 2
    yield return new WaitForSeconds(StimulusDuration); // wait for 1 second
    for comfort
    }

    StimulusMesh[SceneOrder[6]].SetActive(false);
    StimulusMesh[0].SetActive(true);

    yield return null;
}

// Use this for initialization
void Start()
{
    // https://www.youtube.com/watch?v=mAeTRCT0qZg
    // https://www.codeproject.com/Questions/384247/How-to-read-from-csv-file-
    using-csharp-net

    RenderSettings.ambientMode = UnityEngine.Rendering.AmbientMode.Flat;
    RenderSettings.ambientLight = AmbientColor;

    ShuffleArray(SceneOrder);

    Debug.Log("calling RunExperiment");
    StartCoroutine(RunExperiment());
}

// Update is called once per frame
void Update()
{
}
}
```

*Figure A.110. Unity Script for VR Project – Preview (pg 2/2)*

### Acqknowledge Scripting

```
; SCRIPT TO RUN ON SINGLE FILE. (N.B. batch will just call this and repeat for each file)
; Used Variables: U$

Call "DigInToStim"
Call "TrimWave"
Call "DigInToStim"
Call "RenameStim"
Call "ManageChannels"
Call "Presentation"

; Convert digital stim to global markers
; trim the wave at 3s before first buffer item
; Rerun digital stim to resync trimmed data
; Rename the markers to the correct names
; Put the channels in the standard format (CH1=ECG, CH2=EDA, CH3=RL
; Put the channels in the standard format (CH1=ECG, CH2=EDA, CH3=RL

End
```

*Figure A.111. Acqknowledge Scripting – #1 Setup – SingleFile (pg 1/1)*

```

;Biopac's own script to create markers at the digital inputs

; Digital Input to Stim Events
;
; This macro is used to define stimulus events for data where stim markers
; have been acquired on the digital inputs of an MP device. The digital inputs
; are treated as a base-2 encoded number, big endian bit ordering (bit zero is
; the lowest indexed digital channel).
;
; The label of each stimulus event is set to the number as encoded on the
; digital channels. This allows for use of the label matching features of the
; cycle detector to perform stimulus-specific analysis.

// Load translation
LOADTRANSLATIONFILE "Stim-Response"

; Globals:
;
; A      digital channel subset method, 1 = D0-D7, 2 = D8-D15, 3 = D0-D15, 4 = Specific channel subset
; B      transition latency, 0 by default.
; T      threshold level for channel subsets that include non-digital channels (A=4)
; U      if true, we do have at least one non-digital channel and need to use
;         a threshold. If false, all digital channels.
;
; Arrays:
;
; "_diseDigitalChans"      filled with indexes of valid digital channels that
;                           should be interpreted as the stimulus markers, in
;                           order of increasing bit significance

// get user's selected area so we can restore it when complete
A = 1
j = HCursor1
k = HCursor2

; search to see if the graph already has stimulus events. If it does, query
; whether they should be replaced or augmented

SearchForMarker "stim", -2, 1, a
if a <> 0
    ; Prompt QT_TRANSLATE_NOOP("Digital Input to Stim Events", "Stimulus events are already present in the graph. Erase them:
    b = 1
    if b = 1
        ; user requested existing events should be erased

clearPriorStimEvents_loop:
    if a <> 0
        DeleteMarker a
        SearchForMarker "stim", -2, 1, a
        goto clearPriorStimEvents_loop
    endif
endif
if b = 3
    ; user canceled...halt macro execution

    Halt
endif
endif
endif

```

*Figure A.112. Acqknowledge Scripting – #2 Setup – DigInToStim (pg 1/9)*



```

i = 0 ; next available index in digital channel array

d0d15ChanSearch_loop:
; if below terminates at D15, inclusive
if c < 36
    Get Channel Enable c, z
    if z = true
        ; channel contains data. Assume it is from our digital input.
        Array "_diseDigitalChans" Set i, c
        i = i + 1 ; increment to next array index
    endif

    ; move onto next channel

    c = c + 1
    goto d0d15ChanSearch_loop
endif

if A = 4
; [ed] 2/2/09 Allow events to be defined from any channels in the graph.
; This allows event definition via analog channels which are used for
; switches or other hardware that requires isolation.

ChooseMultipleChannels QT_TRANSLATE_NOOP("Digital Input to Stim Events", "Trigger Channels"), QT_TRANSLATE_NOOP("C
Array "_diseTriggerChanSet" Length, z
if z = 0
    ; user canceled the dialog, so halt
    Halt
endif

i = 0 ; next available index in digital channel array
t = 0 ; set to 1 if trigger is required

j = 0 ; index into _diseTriggerChanSet array

allChanSearch_loop:
Array "_diseTriggerChanSet" Length, z
if j < z
    Array "_diseTriggerChanSet" Get j, y
    if y = 1
        ; user enabled the channel as a trigger channel

        Array "_diseDigitalChans" Set i, j
        i = i + 1 ; next entry in the digital chans array

        if or(less(j,20), less(39,j)) = true
            // we have an analog or calculation channel, so we'll need to
            // prompt for a threshold level

            t = 1
        endif
    endif

    ; goto next channel index in the array

    j = j + 1
    goto allChanSearch_loop
endif

; check if we need to prompt for a threshold level

if t = 1
    U = 1 ; indicate we have a non-digital channel

trigThreshLoop:
    GetNumber QT_TRANSLATE_NOOP("Digital Input to Stim Events", "Trigger threshold:"), "", T, z, false
    if z = 1

```

Figure A.113. Acqknowledge Scripting – #2 Setup – DigInToStim (pg 2/9)

```

; determine the range of digital channels that should be used to define
; stimulus events.

if or(less(A, 1), less(3, A)) = true
    ; set a default value for A only if
    A = 1
endif
;ChooseItem QT_TRANSLATE_NOOP("Digital Input to Stim Events", "Extract stimuli from:"), A, QT_TRANSLATE_NOOP("Digital Input t
if A = 0
    ; user clicked "cancel", so halt execution
    Halt
endif

U = 0 ; assume all digital channels to start

Array "_diseDigitalChans" Clear
if A = 1
    ; perform valid channel search on lines D0-D7. Digital lines start at graph
    ; channel index 20.

    c = 20 ; graph channel search index, start at D0
    i = 0 ; next available index in digital channel array

d0d7ChanSearch_loop:
    ; if below terminates at D7, inclusive
    if c < 28
        Get Channel Enable c, z
        if z = true
            ; channel contains data. Assume it is from our digital input.
            Array "_diseDigitalChans" Set i, c
            i = i + 1 ; increment to next array index
        endif

        ; move onto next channel

        c = c + 1
        goto d0d7ChanSearch_loop
    endif
endif
if A = 2
    ; perform valid channel search on lines D8-D15. Digital lines start at graph
    ; channel index 20.

    c = 28 ; graph channel search index, start at D8
    i = 0 ; next available index in digital channel array

d8d15ChanSearch_loop:
    ; if below terminates at D15, inclusive
    if c < 36
        Get Channel Enable c, z
        if z = true
            ; channel contains data. Assume it is from our digital input.
            Array "_diseDigitalChans" Set i, c
            i = i + 1 ; increment to next array index
        endif

        ; move onto next channel

        c = c + 1
        goto d8d15ChanSearch_loop
    endif
endif
if A = 3
    ; perform valid channel search on lines D0-D15. Digital lines start at graph
    ; channel index 20.

    c = 20 ; graph channel search index, start at D0

```

Figure A.114. Acqknowledge Scripting – #2 Setup – DigInToStim (pg 3/9)

```

; user canceled the dialog
Halt
endif
if T < 0
    Prompt QT_TRANSLATE_NOOP("Digital Input to Stim Events", "The trigger level cannot be negative."), QT_TRA
    goto trigThreshLoop
endif
endif

; make sure we have at least one digital channel
Array "_diseDigitalChans" Length, z
if z = 0
    if A = 1
        Prompt QT_TRANSLATE_NOOP("Digital Input to Stim Events", "No valid digital channels were found in the graph. Verif
    endif

    if A = 2
        Prompt QT_TRANSLATE_NOOP("Digital Input to Stim Events", "No valid digital channels were found in the graph. Verif
    endif

    if A = 3
        Prompt QT_TRANSLATE_NOOP("Digital Input to Stim Events", "No valid digital channels were found in the graph. Verif
    endif

    if A = 4
        Prompt QT_TRANSLATE_NOOP("Digital Input to Stim Events", "None of the specified channels were found in the graph
    endif

    Halt
endif

; [ed] 7/14/06 Add in a transition latency amount to discard transitions
; occurring within a window. Some hardware is not able to transition all
; lines with precision and may require a certain amount of time to actually
; execute a transition.

B = 0.000001
getLatency:
;GetTimeNumber "Transition latency:", B, z
if z = 0
    ; user canceled
    Halt
endif
if B < 0
    Prompt QT_TRANSLATE_NOOP("Digital Input to Stim Events", "The transition latency cannot be negative."), QT_TRANSLATE_I
    goto getLatency
endif

; verify we have at least two available channels that we need to do our
; temporary processing

Get NumChannels z
Get MaxNumChannels y
x = y - z
if x < 2
    Prompt QT_TRANSLATE_NOOP("Digital Input to Stim Events", "Not enough available channels to perform processing. Please n
    Halt
endif

; [ed] 10/28/08 Transformation cancel support

Transform AsyncProgress Show
Transform AsyncProgress SetMessage QT_TRANSLATE_NOOP("Digital Input to Stim Events", "Converting digital input to stim events...

```

*Figure A.115. Acqknowledge Scripting – #2 Setup – DigInToStim (pg 4/9)*

```

; we have analog or calc channels, so use a non-zero threshold test

Z$ = "SC+IF(LESS(CH"
Z$ = Z$ + STR$(a, 0)
Z$ = Z$ + ", T), 0, "
z = 2 ^ i
Z$ = Z$ + STR$(z, 0)
Z$ = Z$ + ")"
endif

; our STR$ conversion inserts spaces, but our equation syntax requires no whitespace
; between CH and the digit. Chomp out all the whitespace.

convertDigChans_chomp_whitespace:
RegEx Replace "\s", Z$, "", z
if z <> -1
; continue on and get the next whitespace
goto convertDigChans_chomp_whitespace
endif

; perform the transformation to add in appropriate power of two

Select Wave c
Edit SelectAll
Transform Expression Z$

; move onto the next digital channel

i = i + 1
goto convertDigChansToBase10_loop
endif

; at this point, the waveform at index "c" contains the base 10 value at each
; sample point in the waveform. Construct our events as follows:
;
; 1 - Make a triggering signal to identify positions where the stimulus trigger
; signal changes value.
;
; 2 - Define stimulus events at each value change using the peak detector
;
; 3 - Run through all stimulus events and set labels to correspond to trigger
; signal value.

; triggering signal construction for peak detection. Store triggering signal
; index into variable "d"

Select Wave c
Edit SelectAll
Edit Duplicate, d
Select Wave d

; assemble expression whose output will be one on transitions to non-zero
; stimulus index values

Z$ = "IF(EQUAL(CH"
Z$ = Z$ + STR$(c, 0)
Z$ = Z$ + ", CH"
Z$ = Z$ + STR$(c, 0)
Z$ = Z$ + "(-1)), 0, NOT(EQUAL(CH"
Z$ = Z$ + STR$(c, 0)
Z$ = Z$ + ", 0)))"

; remove whitespace inserted by STR$

triggerSignal_strip_whitespace:
RegEx Replace "\s", Z$, "", z
if z <> -1

```

Figure A.116. Acqknowledge Scripting – #2 Setup – DigInToStim (pg 5/9)

```

; convert the base 2 encoded signal on the digital channels contained in
; the _diseDigitalChans array into a single channel (base 10 floating point).
; Index of our unencoded waveform will be stored in variable "c"

Array "_diseDigitalChans" Length, l

// bit 0 is in the first digital channel. We'll do this channel with a duplicate
// and a limit to convert the 5V digital signal into 1.0
Array "_diseDigitalChans" Get 0, a
Select Wave a
Edit SelectAll
Edit Duplicate, c
Select Wave c
; [ed] 11/13/08 Keep the waveform at the sampling rate of the graph for proper
; cursor snapping to graph sampling rate when checking for transitions at
; consecutive sample positions. Bug #12025
Get Channel Divider c, z
if z <> 1
    Transform ResampleWave 1, Padding
endif
if or(less(a,20),less(39,a)) = true
    ; analog or calculation channel, so we need to use a threshold function
    ; to find locations below/above the analog threshold

    Transform Function Threshold T, T
else
    ; digital channel, so assume [0-5V] input

    Transform Function Limit 0, 1
endif

; [ed] 10/28/08 Transformation cancel support
Transform IsCanceled z
if z = true
    Transform AsyncProgress Hide
    Halt
endif

; continue processing higher order bits contained in subsequent digital channels.

i = 1
convertDigChansToBase10_loop:
if i < l
    ; [ed] 10/28/08 Transformation cancel support
    Transform IsCanceled z
    if z = true
        Transform AsyncProgress Hide
        Halt
    endif

    ; construct an expression that will add the appropriate power of 2 to
    ; the waveform at index "c" whenever the digital channel is non-zero

    Array "_diseDigitalChans" Get i, a

    if U = false
        ; all digital channels, so we can use an equal to zero test to get our
        ; level

        Z$ = "SC+IF(EQUAL(CH"
        Z$ = Z$ + STR$(a, 0)
        Z$ = Z$ + ", 0), 0, "
        z = 2 ^ i
        Z$ = Z$ + STR$(z, 0)
        Z$ = Z$ + ")"
    else

```

Figure A.117. Acqknowledge Scripting – #2 Setup – DigInToStim (pg 6/9)

```

        goto changedValue_insert
    endif

    ; move to the next marker and continue searching
    n = n + 1
    goto checkStim_loop
endif

; remove any stimulus transitions occurring within the latency time

if B > 0
    n = 1
removeCloseStim_loop:
    SearchForMarker "stim", -1, n, n
    if n <> 0
removeCloseStim_loop2:
        ; [ed] 10/28/08 Transformation cancel support
        Transform IsCanceled z
        if z = true
            Transform AsyncProgress Hide
            Halt
        endif

        SearchForMarker "stim", -1, ( n + 1 ), z
        if z <> 0
            Get Marker Time n, t
            Get Marker Time z, u
            if ( u - t ) < B
                DeleteMarker z
                ; continue searching for other markers within the latency
                ; period
                goto removeCloseStim_loop2
            endif
        endif

        ; search for latency windows around subsequent markers

        n = n + 1
        goto removeCloseStim_loop
    endif
endif

; loop over all stimulus events and change their labels to match the value of
; the unencoded stimulus number from waveform "c".
;
// Presently, AcqKnowledge 3.9.0 performs substring matching only for event
// driven cycle location. In order to distinguish between different stimulus
// events, we need to make the label for each stimulus type unique. We'll use
// prefix zeros to make sure we have all unique labels. The number of leading
// zeros required is the maximum number of digits needed to represent the highest
// numbered stimulus in base 10.

Select Wave c
Edit SelectAll
Update MMTs
m = floor(log10(Max)) + 1 ; number of base 10 digits needed to express max stim index

n = 1
labelStimMarker_loop:
SearchForMarker "stim", -1, n, n
if n <> 0
    Get Marker Time n, t
    ; [ed] 7/14/06 Use the maximum value within the latency window
    Set HCursor t, ( t + B )
    l = Max

    Z$ = ""

```

Figure A.118. Acqknowledge Scripting – #2 Setup – DigInToStim (pg 7/9)

```

        ; continue on and get the next whitespace
        goto triggerSignal_strip_whitespace
    endif
    Transform Expression Z$
    ; [ed] 10/28/08 Transformation cancel support
    Transform IsCanceled z
    if z = true
        Transform AsyncProgress Hide
        Halt
    endif

    // perform peak detection for defining our stimulus events. We'll keep our
    // events as global events.

    Transform FindPeak Cycle Peak d, Positive, 0.25, Fixed
    Transform FindPeak Selection Peak PreviousPeak, 0, 0
    Transform FindPeak Output Disable
    Transform FindPeak Output Events Enable 1, "stim", -1, "", Right, AtEdge
    Set HCursor 0, 0
    Transform FindPeak Execute All
    ; [ed] 10/28/08 Transformation cancel support
    Transform IsCanceled z
    if z = true
        Transform AsyncProgress Hide
        Halt
    endif

    ; the peak detection above will miss transitions that occur at consecutive
    ; sample positions. Run through all locations and check to see if we need
    ; to add in new transitions.

    Get SampleTime, z
    z = z / 1000 ; convert into seconds for use with other macro commands
    n = 1
    checkStim_loop:
    SearchForMarker "stim", -1, n, n
    if n <> 0
        Get Marker Time n, t
    changedValue_insert:
        ; [ed] 10/28/08 Transformation cancel support
        Transform IsCanceled y
        if y = true
            Transform AsyncProgress Hide
            Halt
        endif

        t = t + z
        Set HCursor t, t

        ; [ed] 7/24/06 Make sure we always snap onto the next sample position
        ; just in case we have floating point error that causes our time cursor
        ; to lie off of the actual sample location. If it goes off of sample
        ; locations, infinite loops may occur if we get rounded down to the
        ; previous sample position of marker n while executing InsertMarker.
        ; Bug #8156

        ; [ed] 9/9/09 Add an explicit round up so we always go to the higher
        ; sample to avoid infinite loops. Bug #13487

        SnapCursorsToSamples SnapRight, GraphSampleRate

        if Value = 1
            ; we had a transition immediately following our initial change in
            ; value. Insert another marker and continue checking for more
            ; transitions

            InsertMarker "", -1, "stim"

```

*Figure A.119. Acqknowledge Scripting – #2 Setup – DigInToStim (pg 8/9)*

```

; add prefix zeroes, if required

z = m - ( floor(log10(l)) + 1 )
prefixZero_loop:
; [ed] 10/28/08 Transformation cancel support
Transform IsCanceled y
if y = true
    Transform AsyncProgress Hide
    Halt
endif

if z > 0
    Z$ = Z$ + "0"
    z = z - 1
    goto prefixZero_loop
endif

; add on our stim index

Z$ = Z$ + STR$(l, 0)

; strip out whitespace from the label that was inserted by Z$

stimLabel_strip_whitespace:
RegEx Replace "\s", Z$, "", z
if z <> -1
    ; continue on and get the next whitespace
    goto stimLabel_strip_whitespace
endif

; change marker label

RenameMarker n, Z$

; move onto the next marker and resume searching for any remaining stim
; events

n = n + 1
goto labelStimMarker_loop
endif

; remove our temporary channels and clear arrays to free memory

Select Wave c
Edit Remove
Select Wave d
Edit Remove
Array "_diseDigitalChans" Clear

; [ed] 10/28/08 Transformation cancel support

Transform AsyncProgress Hide

; update measurements and visual area to sync new markers and the like

Set HCursor j, k
// user's selection on entry of the macro routines
Show Markers
// make sure our output is visible!
Update MMTs
Update All

End

```

Figure A.120. Acqknowledge Scripting – #2 Setup – DigInToStim (pg 9/9)



```

;TRIM THE WAVE AT 3S BEFORE THE FIRST BUFFER AND 3 SECS AFTER THE END OF THE CIT
; used Variables: b e w A P$ I Q y Z$ u q s

edit selectall                ; select the whole area
b = hcursor1                  ; set b as the beginning of the area in seconds
e = hcursor2                  ; set e as the end of the area in seconds

; REMOVE APPEND MARKERS

Get Marker Count A            ; Get number of markers
w = A                          ; Initially set w to number of markers
RemoveAppend:                 ; Remove append marks in data

    Get Marker Type w, P$     ; Get marker type and assign to P$
    if P$ = "apnd"            ; Check if maker is a append marker
        DeleteMarker w       ; if so delete that marker
    endif                    ; done

    w = w - 1                 ; Go to the next marker (counting from the back)

    if w > 0                   ; check to see if there are still markers left
        goto RemoveAppend    ; if so repeat loop
    endif                    ; done

; CHECK TO SEE IF THERE ARE START AND ENDS OF CIT - IF NOT ADD THEM IN

Get Marker Count Q            ; Get new marker count
I = Q                          ; Initially set I to number of markers
y = 0                          ; starting from 1st marker and working our way up
u = 0                          ; Set u = 0 as default to say we don't have an end
q = 0                          ; Set q = 0 as default to say we don't have a START
CheckStartandEnd:             ; Check if there are start and end markers

    Get Marker Text y, Z$     ; Check marker text

    if Z$ = "100"              ; if 100 (START)
        q = q + 1              ; Then add 1 to q so its no longer 0 (to indicate that we have a start)
    endif                    ; done

    if y = Q                   ; If y is at the last marker (Q)
        if Z$ = "106"          ; then check if its 106 (END)
            u = u + 1          ; If so then add 1 to u to indicate that we have an end
        endif                ; done
    endif                    ; done

    if y = Q                   ; Check to see if have go to the last marker
        goto EndCheck          ; if so then end this loop
    else                       ; or
        y = y + 1              ; add 1 to the marker count
        goto CheckStartandEnd  ; and repeat loop
    endif                    ; done
EndCheck:

    if q < 1                   ; if we didn't find a start marker (i.e. q = 0 still)
        set hcursor b, b       ; then set the hcursor to that position
        InsertMarker "100", -1, "stim" ; and add a start 100 marker
    endif                    ; done

    if u < 1                   ; if we didn't find a end marker (i.e. u = 0 still)
        set hcursor (e-1.01), (e-1.01) ; then set the hcursor to that position minus 1s
        InsertMarker "106", -1, "stim" ; and add a start 106 marker
    endif                    ; done

```

Figure A.121. Acqknowledge Scripting – #3 Setup – TrimWave (pg 1/2)

; CHECK FOR ADDITIONAL START MARKERS TO INDICATE ANOTHER START OF TEST HAS OCCURED (E.G. PRACTICE)

```

Get Marker Count R                                ; Get new marker count

FindStart:                                         ; In the case where practice data is present we want to find the second st
    I = I - 1                                     ; I is still the marker count from above
    Get Marker Text I, X@                         ; Get the marker text of the marker I

    if I > 4000                                    ; Debug loop incase it never find a 100
        goto findCondEnd                         ; 'force' end this loop
    endif                                         ; done

    if X@ = "100"                                  ; If marker is start
        Get Marker Time I, s                     ; Then get the marker position (time) as s
        goto Find103                             ; and go to find the next 103
    else                                         ; or
        goto FindStart                           ; Repeat loop
    endif                                         ; done

Find103:                                           ; Now look for
    I = I + 1                                     ; look for the next marker after the identified 100
    SearchForMarker "stim", -2, I, d             ; now search all stim markers after the found 100 marker and return mark

    Get Marker Text d, X@                         ; Get the text of this marker as X$

    if I > 4000                                    ; Debug loop incase it never find a following marker
        goto findCondEnd                         ; 'force' end this loop
    endif                                         ; done

    if X@ = "103"                                  ; if this found marker is a 103
        Get Marker Time d, s                     ; then get maker time of that marker and set s (as the new start time)
        I = R                                     ; set I to equal the marker count R
        goto findCondEnd                         ; end the loop
    else                                         ; or
        goto find103                             ; Repeat loop to find the 103
    endif                                         ; done

findCondEnd:

Get Marker Text I, Y@                             ; Check marker text of marker I (now working from end)
    if I > 4000                                    ; Debug loop incase it never find a following marker
        goto debugEnd                           ; 'force' end this loop
    endif                                         ; done

    if Y@ = "106"                                  ; Check if the marker is 106
        Get Marker Time I, f                     ; if so then get the time a f (as the new end)
        goto debugEnd                             ; now end the loop
    else                                         ; or
        I = I - 1                                 ; next marker back
        goto findCondEnd                         ; repeat loop
    endif                                         ; done

debugEnd:                                         ; finished

; TRIM THE WAVE

f = f + 3.02                                     ; time of the end of the wave from above plus 0.02 to account for sample
Set HCursor f, e                                 ; set the hcursor that this point and the actual end of the graph e
SnapCursorsToSamples SnapToClosest GraphSampleRate ; snap to the nearest sample
Edit ClearAll                                    ; clear everthing between f and e

Set HCursor b, (s-3)                             ; set the hcursor at the actual start of the wave and at the point of the first
SnapCursorsToSamples SnapToClosest GraphSampleRate ; snap to the nearest sample
Edit ClearAll                                    ; clear everthing between b and s-3

Set HaxisOffset 0                                ; this sets the time axis back to 0

```

Figure A.122. Acqknowledge Scripting – #3 Setup – TrimWave (pg 2/2)

; CHANGE ALL THE STIMULI EVENT MARKERS TO LABELLED MARKERS (E.G. PROBE ETC)  
 ; Used Variables: A\$ C\$ P\$ I\$ T\$ E\$ Z\$ B\$ Q\$ T\$ X\$ c

; NAMES OF STIMULI

|            |              |
|------------|--------------|
| A@ = "100" | ; START      |
| C@ = "101" | ; Start CIT  |
| P@ = "102" | ; Probe      |
| I@ = "103" | ; Irrelevant |
| T@ = "104" | ; Target     |
| E@ = "105" | ; EndCIT     |
| Z@ = "106" | ; END        |
| B@ = "107" | ; Blank      |
| Q@ = "108" | ; Question   |

; ADD MISSING STARTS

|                              |                                 |
|------------------------------|---------------------------------|
| Set HCursor 0,0              | ; Set Hcurser to start of grap  |
| InsertMarker A\$, -1, "stim" | ; Insert a START at this poin   |
| InsertMarker C\$, -1, "stim" | ; Insert a StartCIT at this poi |

;CHANGE THE NAME OF ALL STIMULI (LIGHTBULBS) TO TYPE USR1 AND THE CORRECT NAMES

|  |   |
|--|---|
| Set HCursor 0,0  | ; Set Hcurser to start of grap          |
| Transform FindPeak Cycle Event "stim", -1, StartLabel, A@, "stim", -1, EndLabel, A@, SingleEvent | ; Find stimuli labeld with the string ( |
| Transform FindPeak Selection Event StartEvent, 0, StartEvent, 0                                  | ; Select that event time                |
| Transform FindPeak Output Events Enable 1, "anlg", -1, "START", Left, AtEdge                     | ; Insert a new event that thi           |
| Transform FindPeak Execute All   | ; Execute the above                     |

|  |   |
|--|---|
| Set HCursor 0,0  | ; Set Hcurser to start of grap          |
| Transform FindPeak Cycle Event "stim", -1, StartLabel, C@, "stim", -1, EndLabel, C@, SingleEvent | ; Find stimuli labeld with the string ( |
| Transform FindPeak Selection Event StartEvent, 0, StartEvent, 0                                  | ; Select that event time                |
| Transform FindPeak Output Events Enable 1, "anlg", -1, "StartCIT", Left, AtEdge                  | ; Insert a new event that this event    |
| Transform FindPeak Execute All   | ; Execute the above                     |

|  |   |
|--|---|
| Set HCursor 0,0  | ; Set Hcurser to start of grap          |
| Transform FindPeak Cycle Event "stim", -1, StartLabel, P@, "stim", -1, EndLabel, P@, SingleEvent | ; Find stimuli labeld with the string ( |
| Transform FindPeak Selection Event StartEvent, 0, StartEvent, 0                                  | ; Select that event time                |
| Transform FindPeak Output Events Enable 1, "usr1", -1, "Probe", Left, AtEdge                     | ; Insert a new event that thi           |
| Transform FindPeak Execute All   | ; Execute the above                     |

|  |   |
|--|---|
| Set HCursor 0,0  | ; Set Hcurser to start of grap          |
| Transform FindPeak Cycle Event "stim", -1, StartLabel, I@, "stim", -1, EndLabel, I@, SingleEvent | ; Find stimuli labeld with the string ( |
| Transform FindPeak Selection Event StartEvent, 0, StartEvent, 0                                  | ; Select that event time                |
| Transform FindPeak Output Events Enable 1, "usr1", -1, "Irrelevant", Left, AtEdge                | ; Insert a new event that this event    |
| Transform FindPeak Execute All   | ; Execute the above                     |

|  |   |
|--|---|
| Set HCursor 0,0  | ; Set Hcurser to start of grap          |
| Transform FindPeak Cycle Event "stim", -1, StartLabel, T@, "stim", -1, EndLabel, T@, SingleEvent | ; Find stimuli labeld with the string ( |
| Transform FindPeak Selection Event StartEvent, 0, StartEvent, 0                                  | ; Select that event time                |
| Transform FindPeak Output Events Enable 1, "usr1", -1, "Target", Left, AtEdge                    | ; Insert a new event that thi           |
| Transform FindPeak Execute All   | ; Execute the above                     |

|  |   |
|--|---|
| Set HCursor 0,0  | ; Set Hcurser to start of grap          |
| Transform FindPeak Cycle Event "stim", -1, StartLabel, E@, "stim", -1, EndLabel, E@, SingleEvent | ; Find stimuli labeld with the string ( |
| Transform FindPeak Selection Event StartEvent, 0, StartEvent, 0                                  | ; Select that event time                |
| Transform FindPeak Output Events Enable 1, "usr1", -1, "EndCIT", Left, AtEdge                    | ; Insert a new event that thi           |
| Transform FindPeak Execute All   | ; Execute the above                     |

|  |   |
|--|---|
| Set HCursor 0,0  | ; Set Hcurser to start of grap          |
| Transform FindPeak Cycle Event "stim", -1, StartLabel, Z@, "stim", -1, EndLabel, Z@, SingleEvent | ; Find stimuli labeld with the string ( |
| Transform FindPeak Selection Event StartEvent, 0, StartEvent, 0                                  | ; Select that event time                |
| Transform FindPeak Output Events Enable 1, "anlg", -1, "END", Left, AtEdge                       | ; Insert a new event that thi           |
| Transform FindPeak Execute All   | ; Execute the above                     |

|                 |                                |
|-----------------|--------------------------------|
| Set HCursor 0,0 | ; Set Hcurser to start of grap |
|-----------------|--------------------------------|

Figure A.123. Acqknowledge Scripting – #4 Setup – RenameStim (pg 1/2)

```

Transform FindPeak Cycle Event "stim", -1, StartLabel, B@, "stim", -1, EndLabel, B@, SingleEvent ; Find stimuli labeled with the string (
Transform FindPeak Selection Event StartEvent, 0, StartEvent, 0 ; Select that event time
Transform FindPeak Output Events Enable 1, "usr1", -1, "Blank", Left, AtEdge ; Insert a new event that thi
Transform FindPeak Execute All ; Execute the above

Set HCursor 0,0 ; Set Hcurser to start of grap
Transform FindPeak Cycle Event "stim", -1, StartLabel, Q@, "stim", -1, EndLabel, Q@, SingleEvent ; Find stimuli labeled with the string (
Transform FindPeak Selection Event StartEvent, 0, StartEvent, 0 ; Select that event time
Transform FindPeak Output Events Enable 1, "usr1", -1, "Question", Left, AtEdge ; Insert a new event that this event
Transform FindPeak Execute All ; Execute the above

; DELETE ALL THE OLD STIM EVENT MARKERS (LIGHTBULBS) and Questions and Blanks
Set HCursor 0,0 ; Set Hcurser to start of grap
Get Marker Count c ; Get the number of markers

MarkerDeleteLoop: ; Loop through each marker

    Get Marker Type c, X@ ; Get the marker type and as
    Get Marker Text c, T@ ; Get the marker text and assign to `

    if X@="stim" ; Check the marker type
        DeleteMarker c ; if Stim (Lightbulb) Delete maker
    endif ; Done

    if T@ = "Question" ; Check the marker text
        DeleteMarker c ; if Question then delete
    endif ; Done

    if T@ = "Blank" ; Check the marker text
        DeleteMarker c ; if Blank then delete
    endif ; Done

    if c = 0 ; If we've done all the marke
        goto MarkerDeleteEnd ; ""
    else ; OR
        c = c - 1 ; Next marker
        goto MarkerDeleteLoop ; Repeat loop
    endif ; ""

MarkerDeleteEnd:

; CHECK IF THERE IS AN END (106) AND IF NOT ADD
Get Marker Count c ; Get new marker count
Get Marker Text c, W@ ; Get marker text of last mar

If W@ = "END" ; If END then don't worry
else ; otherwise
    Get marker time c, t ; Get time of that marker
    Set HCursor t+3,t+3 ; Add 3s
    InsertMarker "END", -1, "anlg" ; Insert end marker
endif ; done

End

```

Figure A.124. Acqknowledge Scripting – #4 Setup – RenameStim (pg 2/2)

```

; REFORMAT ALL THE CHANNELS TO THE CORRECT LOCATION AS REQUIRED FOR FURTHER ANALYSIS (so the scripts can work!)
; Variables used: I i a T$ E

;CHECK NUMBER OF CHANNELS
CheckNumberofChannels:
    Get FreeChannelIndex I
    if I < 5
        Select wave 1
        Edit Duplicate
        Goto CheckNumberofChannels
    else
        Goto EndCheckNumberofChannels
    endif
EndCheckNumberofChannels:

; REMOVE REDUNDANT CHANNELS
i = 5
a = 28

BeforeDigSigs:
    Select Wave i
    Edit remove
    i = i + 1

    if i < 20
        goto BeforeDigSigs
    endif

AfterDigSigs:
    Select Wave a
    Edit remove
    a = a + 1

    if a < 60
        goto AfterDigSigs
    endif

Select Wave 0
Edit remove

;SWAP THE CHANNELS AROUND TO THE CORRECT LOCATION
Set HCursor 0,0

Select Wave 1
get Channel Name 1, T@

if T@ = "EDA (0 - 35 Hz)"
    edit selectAll
    Edit Duplicate
    Select Wave 1
    Edit remove
    Select Wave 2
    edit selectAll
    Edit Duplicate
    Select Wave 2
    Edit remove
    Select Wave 5
    Edit SelectAll
    Edit Duplicate
    Select Wave 5
    Edit Remove
    Set Channel 1, Label, "ECG"
    Set Channel 2, Label, "EDA"
    Set Channel 3, Label, "Respiration"

```

Figure A.125. Acqknowledge Scripting – #5 Setup – ManageChannels (pg 1/2)

```

        Set Channel 4, Label, "Finger Pulse"          ; Rename channel to Finger Pulse
    endif                                             ; Done

; ADD CH0 AT THE START TO LATER ADD NOISE TO
; (N.B. CH0 doesn't seem to get involved in stuff as a free channel until after 60 have been filled hence ideal to use as won't affect ana
get Channel Length 1 E                               ; Add CH0 for noise marking later
NewChannel 0, E, 1, "units", "Noise"                ; Rename it as noise
Select wave 24                                       ; Copy channel 24 as it's usually just set at 0
edit SelectAll                                       ; Select all CH24
edit copy                                           ; Copy it
select wave 0                                       ; Paste the data into CH0
edit paste                                          ; ""
edit SelectAll                                       ; Select CH0
Transform AsyncProgress Show
transform Expression "(CH0(0)*0)+1"                 ; Times everything by 0 (to level it) and then add 1 so its a channel with j
Transform AsyncProgress Hide
Set Channel 0, Label, "Noise"                       ; Rename it "Noise"

Select Wave 3                                       ; Remove CH0 if its there
Edit remove                                       ; ""
Select Wave 4                                       ; Remove CH0 if its there
Edit remove                                       ; ""

End

```

*Figure A.126. Acqknowledge Scripting – #5 Setup – ManageChannels (pg 2/2)*

```

AutoHoriz
ResetChart

Set Channel 20, Off
Set Channel 21, Off
Set Channel 22, Off
Set Channel 23, Off
Set Channel 24, Off
Set Channel 25, Off
Set Channel 26, Off
Set Channel 27, Off

Autoscale

End

```

*Figure A.127. Acqknowledge Scripting – #6 Setup – Presentation (pg 1/1)*

```
;Add amplitude of 1 for every global marker on selected wave
```

```
a = 0
b = 0
c = 0
T@ = ""
S = 0
```

```
Set HCursor 0,0
Get Marker Count c
Get Channel Length 1, a
Get FreeChannelIndex b
NewChannel b, a, 1, "volts", "Stimuli"
Select Wave b
```

```
MarkertoPlus2:
```

```
    Get Marker Text c, T@

    if T@="Probe"
        Get Marker Sample c, S
        Set WaveData S, 1
    endif

    if T@ = "Irrelevant"
        Get Marker Sample c, S
        Set WaveData S, 1
    endif

    if T@ = "EndCIT"
        Get Marker Sample c, S
        Set WaveData S, 0.5
    endif

    if T@ = "StartCIT"
        Get Marker Sample c, S
        Set WaveData S, 0.5
    endif

    if c = 0
        goto MarkertoPlus2End
    else
        c = c - 1
        goto MarkertoPlus2
    endif
```

```
MarkertoPlus2End:
```

```
AutoHoriz
ResetChart
Autoscale
```

```
End
```

```
W = 1
;GetNumber "Channel Number" "Channel" W      ; Ask for smoothing value
X = 12                                         ; default setting
;GetNumber "ECG Window Size" "Seconds" X      ; Show window

Select Wave 3
Edit remove
Select Wave 4
Edit remove

Call "RRInterval"                            ; Calculates the RR interval and converts to BPM as the sm
Call "HRFunctionv2"                          ; determines the 3s baseline window and subtracts from be

Select Wave 6
Edit Duplicate
Edit remove
Select Wave 4
Edit remove

Set Channel 3, Label, "HR"

End
```

*Figure A.129. Acqknowledge Scripting – #8 ECG Single File (pg 1/1)*



```

; BIOPACS RR INTERVAL EXTRACTION SCRIPT MODIFIED BY DN

LOADTRANSLATIONFILE "Hemodynamics" ;Load translation

G = 1 ;Graph output only

IsECGPUWAVEAvailable a
if a = false
    Prompt QT_TRANSLATE_NOOP("ECG Interval Extraction", "ECG Interval detection not available!"), QT_TRANSLATE_NOOP("EC
    Halt
endif

Get NumChannels a
C = 1

Get Channel Length C, z
if z = 0
    Prompt QT_TRANSLATE_NOOP("ECG Interval Extraction", "The channel does not contain any data. Please try again with a diff
    Halt
endif

SearchForMarker "qrs ", C, 1, a
if a = 0
    Select Wave C
    transform ecgpuwave
    SearchForMarker "qrs ", C, 1, a
    if a = 0
        EmbedString A$, QT_TRANSLATE_NOOP("ECG Interval Extraction", "Channel %1 does not appear to contain valid ECG
        Prompt A$, QT_TRANSLATE_NOOP("ECG Interval Extraction", "OK"), "", ""
        Halt
    endif
endif

Transform AsyncProgress Show
Transform AsyncProgress SetMessage QT_TRANSLATE_NOOP("ECG Interval Extraction", "Performing ECG interval extraction...")

Show Measurements
Get MMTUnits Time, I
Set MMTUnits Time, 5

Transform IsCanceled z
if z = true
    Set MMTUnits Time, I
    Transform AsyncProgress Hide
    Halt
endif

Get MeasurementRows r
Set MeasurementRows 3
Get MeasurementColumns y

set measurement 1, HAbs
set measurementchannel 1, C
set measurement ( 1 + y ), deltah
set measurementchannel ( 1 + y ), C
set measurement ( 1 + ( 2 * y ) ), Value
set measurementchannel ( 1 + ( 2 * y ) ), C

; setup event based detection run

set HCursor 0, 0
transform findpeak cycle event "qrs ", C, StartNoLabel, "qrs ", C, EndNoLabel
transform findpeak selection event StartEvent, 0, EndEvent, 0
transform findpeak output disable
array "qrs_starttime" clear

```

1

*Figure A.130. Acqknowledge Scripting – #9 ECG – RRInterval (pg 1/5)*

```

if G = 5
    u = 1
endif
if u = 1
    Get NumChannels z
    Get MaxNumChannels y
    z = y - z
    if z < 9
        Transform AsyncProgress Hide
        Prompt QT_TRANSLATE_NOOP("ECG Interval Extraction", "There are not enough available channels to display the output")
        Halt
    endif

    Get MaxLength l

    Get FreeChannelIndex a
    array "outputchans" set 0, a
    NewChannel a, l, 1, QT_TRANSLATE_NOOP("ECG Interval Extraction", "seconds"), QT_TRANSLATE_NOOP("ECG Interval Extraction", "seconds")
endif

;; increment variables for this loop:
;; a = index of cycle, into qrs_interval
;; b = bad cycle count
;; f -> set to 1 if one of the searches fails

a = 0
b = 0

myscript_loop1:
array "qrs_starttime" length, z
if a < z
    ; [ed] 10/27/08 Transform cancel support.
    Transform IsCanceled z
    if z = true
        ; close any temporary output and flush text cache

        if t = 1
            GraphJournal DisableAppendCache
        endif

        if v = 1
            ExcelSpreadsheet "_out" Delete
        endif

        Transform AsyncProgress Hide
        Halt
    endif

    f = 0

    ;;; get starting and ending times for this cycle

    array "qrs_starttime" get a, d
    array "qrs_interval" get a, g
    e = d + abs(g)
    Get FirstTOffset z
    ; our intervals are in absolute time, but cursors are axis relative
    J = d - z
    K = e - z

    ;;; output cycle index

    if t = 1
        A$ = STR$(a+1,0)
    endif
endif

```

Figure A.131. Acqknowledge Scripting – #9 ECG – RRInterval (pg 2/5)

```

transform findpeak output measurements enablearray 0, "qrs_starttime"
array "qrs_interval" clear
transform findpeak output measurements enablearray (y), "qrs_interval"
array "qrs_height" clear
transform findpeak output measurements enablearray (2*y), "qrs_height"
transform findpeak execute all

Set MeasurementRows r

Transform IsCanceled z
if z = true
    Set MMTUnits Time, I
    Transform AsyncProgress Hide
    Halt
endif

Set MMTUnits Time, I

;;; Output textual header

Transform AsyncProgress SetMessage QT_TRANSLATE_NOOP("ECG Interval Extraction", "Assembling output...")

t = 0
if G = 0
    t = 1
endif
if G = 2
    t = 1
endif
if G = 5
    t = 1
endif

if t = 1
    GraphJournal EnableAppendCache
    GraphJournal append "\r"
    EmbedString A$, QT_TRANSLATE_NOOP("ECG Interval Extraction", "ECG Analysis of CH%1, "), STR$(C,0)
    //A$ = STR$(C,0) + ", "
    GraphJournal append A$
    Get Channel Name, C, A$
    GraphJournal append A$
    GraphJournal append "\r\r"
    ; [ed] 9/10/09 Fix unterminated string constant.
    GraphJournal append "Cycle"
    GraphJournal append "\t"
    GraphJournal append QT_TRANSLATE_NOOP("ECG Interval Extraction", "Time")
    GraphJournal append "\t"
    GraphJournal append QT_TRANSLATE_NOOP("ECG Interval Extraction", "RR-I")
    GraphJournal append "\r"
endif

array "average" set 0, 0
array "average" set 1, 0

;; construct graphical output channels

u = 0
if G = 1
    u = 1
endif
if G = 2
    u = 1
endif
if G = 4
    u = 1
endif

```

Figure A.132. Acqknowledge Scripting – #9 ECG – RRInterval (pg 3/5)

```

        GraphJournal append A$
        GraphJournal append "\t"
    endif

    if v = 1
        ExcelSpreadsheet "_out" SetCellValue ( 3 + a ), 0, ( a + 1 )
    endif

    ;;; output time

    array "qrs_starttime" get a, g
    if t = 1
        A$ = STR$(g,5)
        GraphJournal append A$
        GraphJournal append "\t"
    endif
    if v = 1
        ExcelSpreadsheet "_out" SetCellValue ( 3 + a ), 1, g
    endif

    ;;; output RR interval
    array "qrs_interval" get a, g
    h = abs(g)
    if t = 1
        A$ = STR$(h,5)
        GraphJournal append A$
        GraphJournal append "\t"
    endif
    if u = 1
        array "outputchans" get 0, I
        L = h
        ;call "SetWaveValue"
        ;;;;;;;;;;;;;;
        ;
        ; SetWaveValue
        ;
        ;;;;;;;;;;;;;;

        ; This function sets the value of a waveform between two time locations
        ; to be a constant value. It mimics ConnectEndpoints, but without the
        ; threading overhead.

        ; PARAMETERS:
        ;     I - Channel to be set
        ;     J - Start time
        ;     K - End time
        ;     L - new value

        ; Edward Peterlin
        ; 3/10/03

        Select Wave I
        Set HCursor J, J
        w = Samples
        Set HCursor K, K
        x = Samples
        Set WaveDataRange w, x, L
    endif
    if v = 1
        ExcelSpreadsheet "_out" SetCellValue ( 3 + a ), 2, h
    endif

    ;;; factor the new interval into our averages array

    array "average" get 0, z
    array "average" set 0, z+h
    array "average" get 1, z

```

Figure A.133. Acqknowledge Scripting – #9 ECG – RRInterval (pg 4/5)

```

    array "average" set 1, z+1

;;; close the line of text and go to the next loop

    if t = 1
        GraphJournal append "\r"
    endif
    a = a + 1
    if f = 1
        b = b + 1
    endif
    goto myscript_loop1
endif

;;; update the graph area if we added channels

if u = 1
    Autoscale
    Update All
endif

; [ed] 10/27/08 Transform cancel support.
Transform AsyncProgress Hide

;;; release memory used by arrays

array "average" clear
array "startsearchindex" clear
array "qrs_starttime" clear
array "qrs_interval" clear
array "qrs_height" clear
array "ph_starttime" clear
array "ph_max" clear
array "ph_interval" clear
array "qt_starttime" clear
array "qt_interval" clear
array "st_starttime" clear
array "st_interval" clear
array "prq_starttime" clear
array "prq_interval" clear
array "qrs_complex_starttime" clear
array "qrs_complex_interval" clear
if u = 1
    array "outputchans" clear
endif

ClearChannelMarkers 1
Edit selectAll

Update MMTs

End

```

Figure A.134. Acqknowledge Scripting – #9 ECG – RRInterval (pg 5/5)

```

; TAKES 3S BEFORE EACH STIMULI AND AVERAGES. THEN SUBTRACTS FROM FOLLOWING STIMULI
; Variables used: a i C D$ C$ F

;X = 10                                     ; ECG Time window

;Added 23-1-20 to ensure that the last trial in the CIT is used to calculate mean ECG (and EDA)
Get Marker Count p
p = p - 1
Get Marker Sample p, q
Get Marker time p, o
Set HCursor o,o
InsertMarker "TEMP" -1, "usr1"

; DETERMINE RR INTERVAL CHANNEL
Get NumChannels a                           ; Get number of channels
i = 0                                       ; Set i as 0 for loop
FindChannel:                               ; Loop to find channel with text "RR Interval"
    Get Channel Name i, A@                 ; Get channel label from channel index i

    if i > a                               ; If i is greater than the number of channels
        Halt                               ; If not found then Halt macro
    else                                   ; otherwise
        if A@ = "RR Interval"              ; Check channel name
            c = i                           ; if correct channel then set C as the channel
            Goto ChannelFound               ; End loop
        else                               ; otherwise
            i = i + 1                       ; look at next channel
            Goto FindChannel                 ; repeat loop
        endif                               ; done
    endif                                   ; done
    ChannelFound:                           ; end loop as channel found

D@ = STR$(c, 0)                             ; convert channel index to string character (
D@ = LTRIM$(D@)                             ; remove the blank space at the start
C@ = "60/CH" + D@                           ; create string for transformation expression

select wave c
edit selectall

Transform AsyncProgress Show
Transform Expression C@
Transform AsyncProgress Hide

; Convert RR Interval to HR

; CHANNEL 6 IS NOW RR INTERVAL CONVERTED TO BPM

Get FreeChannelIndex f                       ; Get new free / destination channel and call

Set HCursor 0,0                             ; Set Hcursor to start
set measurement 1, MEAN                      ; Set measurement 1 to Mean
set measurement 2, NONE                      ; Set measurement 2 to none
set measurement 3, NONE                      ; Set measurement 3 to none
set measurement 4, NONE                      ; Set measurement 4 to none
set measurement 5, NONE                      ; Set measurement 5 to none
set measurementchannel 1, c                  ; Set measurement channel to C using measure 1
get measurementXML U$                        ; gets all the above
Set MeasurementXML U$                        ; sets all the above

Transform FindPeak Cycle Event "usr1", -1, startNoLabel, "usr1", -1, EndNoLabel ; Taking the 3s before each stimuli
Transform FindPeak Selection Event StartEvent, 0-0.01, StartEvent, 0           ; ""
Transform FindPeak Output Disable                                                ; Disable output
Transform FindPeak Output Measurements DisableJournal                          ; and journal
Transform FindPeak Output Measurements EnableWave                             ; pasting the result to a wave
Transform FindPeak Execute All                                                    ; executing all to wave F

```

Figure A.135. Acqknowledge Scripting – #10 ECG - HRFunctionv2 (pg 1/4)

```

Get FreeChannelIndex g                                ; Get new free / desination channel and call

Select Wave f                                          ; Selecting wave 7
edit selectAll                                         ; select all
Edit Duplicate                                         ; duplcting it to wave G

Set Channel g, Label, "1s HR"                          ; Renaming wave G to 3s HR
Select Wave f                                          ; selecting wave F
Edit remove                                           ; removing wave F

Set HCursor 0,0                                       ; Setting hcursor to start
select wave g                                         ; Selecting wave G - 3s HR
edit selectAll                                         ; select all

Transform AsyncProgress Show
Transform Delay Seconds 0.02                          ; delay by 3.01 second
Transform AsyncProgress Hide

Get FreeChannelIndex k                                ; Get new free / desination channel and call

Set HCursor 0,0                                       ; Set Hcursor to start
set measurement 1, MAX                               ; Set measurement 1 to Max
set measurement 2, NONE                              ; Set meaasurement 2 to none
set measurement 3, NONE                              ; Set meaasurement 3 to none
set measurement 4, NONE                              ; Set meaasurement 4 to none
set measurement 5, NONE                              ; Set meaasurement 5 to none
set measurementchannel 1, g                          ; Set meaasurement channel to 8 using measure 1
get measurementXML U$                                ; gets all the above
Set MeasurementXML U$                                ; sets all the above

Transform FindPeak Cycle Event "usr1", -1, startNoLabel, "usr1", -1, EndNoLabel ; Stretching wave G over whole stimul
Transform FindPeak Selection Event EndEvent, 0, StartEvent, 0 ; ""
Transform FindPeak Output Disable                    ; Disable output
Transform FindPeak Output Measurements DisableJournal ; disable journal
Transform FindPeak Output Measurements EnableWave    ; paste to wave
Transform FindPeak Execute All                       ; execute all to wave K so its now inline with

select wave g                                         ; Remove non delayed wave
edit Remove                                           ; Remove

Set HCursor 0,0                                       ; Set Hcursor to start
select wave k                                         ; select wave 7, 3s mean wave
edit selectAll                                         ; Select all data

C@ = STR$(c, 0)                                       ; convert channel index to string character (
F@ = STR$(f, 0)                                       ; convert channel index to string character (
C@ = LTRIM$(C@)                                       ; remove the blank space at the start
F@ = LTRIM$(F@)                                       ; remove the blank space at the start
E@ = "CH" + C@                                       ; create string for transformation expressior
E@ = E@ + "-CH"                                       ; C$ should now be 1 / (CHX/60) where X is
E@ = E@ + F@

Transform AsyncProgress Show
transform expression E@                               ; Subtract all 3s wave from RR Interval (CH
Transform AsyncProgress Hide

select wave c                                         ; Remove intial RR Interval wave
edit Remove                                           ; Remove

Get FreeChannelIndex j                                ; Get new free / desination channel and call

select wave k

```

Figure A.136. Acqknowledge Scripting – #10 ECG - HRFunctionv2 (pg 2/4)

```

edit Duplicate
Set Channel j, Label, "CorrectedRR"
set Channel j, Units, "Delta_BPM"
select wave k
edit Remove

; Relabel wave 7 to Correct RR Interval
; Set channel BPM

; TAEK MEAN CORRECTED HR ACROSS EACH STIMULI BEFORE STIMULI AND X NUMBER OF SECONDS

Get FreeChannelIndex h
Set HCursor 0,0
set measurement 1, MEAN
set measurement 2, NONE
set measurement 3, NONE
set measurement 4, NONE
set measurement 5, NONE
set measurementChannel 1, j
get measurementXML U$
Set MeasurementXML U$

; Get new free / desination channel and call
; Set Hcursor to start
; Set measurement 1 to Mean
; Set meaasurement 2 to none
; Set meaasurement 3 to none
; Set meaasurement 4 to none
; Set meaasurement 5 to none
; Set meaasurement channel to J using measure 1
; gets all the above
; sets all the above

Transform FindPeak Cycle Event "usr1", -1, startNoLabel, "usr1", -1, EndNoLabel
Transform FindPeak Selection Event StartEvent, 0, StartEvent, X
Transform FindPeak Output Disable
Transform FindPeak Output Measurements DisableJournal
Transform FindPeak Output Measurements EnableWave
Transform FindPeak Execute All

; Select between events
; Take mean from start of event to start plu
; Disable output
; Disable journal
; enable output wave
; Execute all to wave 6

Get FreeChannelIndex m

Select wave h
Edit Duplicate

Set Channel m, Label, "MeanHR"
set Channel m, Units, "Delta_BPM"

; Rename CHH as MeanHR
; Set channel BPM

Select wave h
Edit remove

; MAKE 1S HR STEPS AFTER EACH STIMULI

ClearChannelMarkers m

Get Marker Count c
Array "_Markers" clear
c = c + 1
i = 0
r = 0
MarkerLoop:
    if i < c
        get marker Type i, X@
        if X@ = "usr1"
            Get Marker Time i, a
            Array "_Markers" set r, a
            r = r + 1
            i = i + 1
            Goto MarkerLoop
        else
            i = i + 1
            goto MarkerLoop
        endif
    endif

array "_Markers" length m
i = 0
loop:
    if i < m

```

Figure A.137. Acqknowledge Scripting – #10 ECG - HRFunctionv2 (pg 3/4)



```

Array "_Markers" get i, a
Array "_Markers" get i + 1, b

t = a
Miniloop:
    if t > b
        i = i + 1
        t = 0
        goto loop
    else
        Set HCursor t,t
        InsertMarker "Temp", j, "usr6"
        t = t + 1
        goto Miniloop
    endif
endif

Array "_Markers" clear
Get FreeChannelIndex I
Set HCursor 0,0
set measurement 1, MEAN
set measurement 2, NONE
set measurement 3, NONE
set measurement 4, NONE
set measurement 5, NONE
set measurementchannel 1, j
get measurementXML U$
Set MeasurementXML U$

Transform FindPeak Cycle Event "usr6", j, startNoLabel, "usr6", j, EndNoLabel
Transform FindPeak Selection Event StartEvent, 0, EndEvent, 0
Transform FindPeak Output Disable
Transform FindPeak Output Measurements DisableJournal
Transform FindPeak Output Measurements EnableWave
Transform FindPeak Execute All

Set Channel I, Label, "1sHR"
set Channel I, Units, "Delta_BPM"

Select Wave j
Edit Remove

; DELETE TEMP marker added just to cover last trial
Set HCursor 0,0
Get Marker Count n

MarkerDeleteLoop:
    Get Marker Text n, T@
    if T@ = "TEMP"
        DeleteMarker n
    endif
    if n = 0
        goto MarkerDeleteEnd
    else
        n = n - 1
        goto MarkerDeleteLoop
    endif
MarkerDeleteEnd:

; Clear marker array
; Get new free / desination channel and call
; Set Hcursor to start
; Set measurement 1 to Mean
; Set meaasurement 2 to none
; Set meaasurement 3 to none
; Set meaasurement 4 to none
; Set meaasurement 5 to none
; Set meaasurement channel to 7 using measure 1
; gets all the above
; sets all the above
; Take mean for each 1s marker placement
; Measure between each 1s marker placeme
; Disable the output
; Disable the journal
; Enable wave output
; Execute all to CH8
; Rename CH8 as 1s HR
; Set channel BPM
; Select CH7 and remove as no longer need
; Remove CH7
; Set Hcurser to start of grap
; Get the number of markers
; Loop through each marker
; Get the marker text and as
; Check the marker text
; if Question then delete
; Done
; If we've done all the marke
; ""
; OR
; Next marker
; Repeat loop
; ""

```

Figure A.138. Acqknowledge Scripting – #10 ECG - HRFunctionv2 (pg 4/4)

```
; SCRIPT TO RUN ON SINGLE FILE. (N.B. batch will just call this and repeat for each file)
; Used Variables: U$

If O = 1
else
    W = 2
    GetNumber "Channel Number" "Channel" W
    S = 1000
    GetNumber "Channel Smooth" "Samples" S
endif
L = 1

Call "EDASetup"
Call "DefineSCREvents"
Call "RemoveOnsets"
Call "PhasicMethod"

End
```

; Ask for smoothing value  
; Smoothing variable 1000 by default  
; Ask for smoothing value

; Prepares EDA and Phasic eda for analysis  
; determines SCR peaks  
; Remove SCR onsets for manual onset determination

*Figure A.139. Acqknowledge Scripting – #11 EDA-SingleFile (pg 1/1)*

```

; EDA PEAK DETECTION (taken from the biopac eda peak detection but modified)

; Define skin conductance response events on an EDA signal. This looks for short term variations using a threshold detection method (
; This SCR detection method is based on:
; Kim KH, Bang SW, Kim SR. Emotion recognition system using short-term monitoring of physiological signals. Med Biol Eng Comput.

If L = 1                                ; Check from batch file (if ran) to see if already cho
else                                    ; Otherwise
S = 1000                                ; Smoothing variable 1000 by default
GetNumber "Channel Smooth" "Samples" S  ; Ask for smoothing value
endif                                    ; done

Transform AsyncProgress Show             ; Open window (purely to allow us to actually close
Select Wave W                           ; Select wave
Transform Smoothing S                   ; smooth
Transform AsyncProgress Hide            ; remove window

LOADTRANSLATIONFILE "Electrodermal Activity" ; Load translation (?)

; EDA PREFERENCES
G = 1                                    ; 1 = graphical only
H = 0.02                                ; SCR Phasic EDA threshold level, umho
I = 1                                    ; SCR detection rejection percentage. SCRs of amp
J = 1                                    ; phasic EDA generation method; 1 = IIR Highpass
K = 1                                    ; smoothing window width for use in baseline estim

p = HCursor1                            ; save user's selection for restoration when we exit
q = HCursor2                            ; save user's selection for restoration when we exit

Get NumChannels a
if a = 0
    Prompt "The graph must contain data in order to perform SCR detection.", "OK", "", "", b
    Halt
endif

A = 2                                    ; holds the tonic eda channel
a = 1                                    ; holds the cancel the action or not setting
b = 1                                    ; holds "construct new phasic" setting
c = 0                                    ; holds "use existing phasic" setting

if a = 0
    Halt
endif

Get Channel Length A, z
if z = 0
    Prompt "The channel does not contain any data. Please try again with a different channel.", "OK", "", "", a
    Halt
endif

; check the phasic EDA channel

Transform AsyncProgress Show
Transform AsyncProgress SetMessage "Constructing phasic EDA..."

Select Wave A
Edit SelectAll
Edit Duplicate, b

ClearChannelMarkers b
Select Wave b

Set HCursor 0, 0
v = Value

```

Figure A.140. Acqknowledge Scripting – #12 EDASetup (pg 1/2)

```

Edit SelectAll
Transform Math Sub v, Wb, Wb
Transform IIRFilter HighPass, 0.05, 0.707

; set units and label

Z$ = "Phasic EDA (CH"
Z$ = Z$ + STR$(A, 0)
Z$ = Z$ + ")"

Set Channel b, On, Tile, Z$, "uS"

; [ed] 10/28/08 Transformation cancel support
Transform IsCanceled z
if z = true
    Transform AsyncProgress Hide
    Halt
endif

Transform AsyncProgress Hide

; set our return variable to the tonic EDA index

Z = b

B = Z ; store index of phasic EDA into our parameter for DefineSCREvents

; check if the tonic signal already has SCR events on it

SearchForMarker "scr ", A, 1, a
if a <> 0
    if b = 2
        Halt
    endif
endif
eraseOldSCREvents_loop:
SearchForMarker "scr ", A, 1, a
if a <> 0
    DeleteMarker a
    goto eraseOldSCREvents_loop
endif

; erase any waveform onset events for the start of SCR

eraseOldWFONEvents_loop:
SearchForMarker "wfon", A, 1, a
if a <> 0
    DeleteMarker a
    goto eraseOldWFONEvents_loop
endif

eraseOldWFOFEvents_loop:
SearchForMarker "wfof", A, 1, a
if a <> 0
    DeleteMarker a
    goto eraseOldWFOFEvents_loop
endif

endif

End

```

*Figure A.141. Acqknowledge Scripting – #12 EDASetup (pg 2/2)*

```

;
;
; DefineSCREvents
;
;
;
; Given a set of tonic and phasic EDA signals, locate skin conductance
; responses based upon peaks in phasic EDA. This will define SCR events on
; the tonic EDA signal.
;
;
; SCR location is performed using thresholding with the threshold specified
; in the user preferences.
;
; We discard

; Inputs:
;
; A - Tonic EDA channel index
; B - Phasic EDA channel index
; H - SCR threshold detection level (from user preferences)
; I - SCR rejection amplitude percentage. SCRs with amplitudes less than this percent of maximum are dropped from the analysis

; Output:
; "scr " typed events on channel A

; [ed] 10/28/08 Transformation cancel support

Transform AsyncProgress Show
Transform AsyncProgress SetMessage "Locating SCRs..."

; first locate all positive crossings in the phasic EDA of our threshold

Transform FindPeak Cycle Peak B, Positive, H, Fixed
Transform FindPeak Selection Peak Thresh, 0, 0
Transform FindPeak Output Disable
Transform FindPeak Output Events Enable, 1, "wfon", A, "", Left, AtEdge
Set HCursor 0, 0
Transform FindPeak Execute All

; [ed] 10/28/08 Transformation cancel support
Transform IsCanceled q
if q = true
    Transform AsyncProgress Hide
    Halt
endif

; locate negative zero crossings after each threshold crossing in the phasic EDA

Transform FindPeak Cycle Event, "wfon", A, StartNoLabel, "wfon", A, EndNoLabel
Transform FindPeak Selection Event StartEvent, 0, EndEvent, 0
Transform FindPeak Output Disable
Transform FindPeak Output Events Enable, 1, "wfon", A, "", Left, Threshold, 0, B, Absolute, Neg
Set HCursor 0, 0
Transform FindPeak Execute All

; remove waveform onset events that did not have a matching zero crossing.
; these correspond to locations where EDA is still increasing but has not yet
; settled, so are just different turning points on the upslope.

i = 0
Z$ = ""
defineSCR_removeUnmatchedWFONEvents_loop:
; [ed] 10/28/08 Transformation cancel support
Transform IsCanceled q
if q = true
    Transform AsyncProgress Hide
    Halt

```

Figure A.142. Acqknowledge Scripting – #13 DefineSCREvents (pg 1/5)

```

endif
SearchForMarker "", A, ( i + 1 ), z
if z > 0
    Get Marker Type, z, Y$
    if i = 0
        ; first marker, seed previous marker type in Z$ and continue to search
        ; for the next marker

        Z$ = Y$
        i = z
        goto defineSCR_removeUnmatchedWFONEvents_loop
    else
        ; check if the immediately preceding marker was also an onset

        EqualString Y$, "wfon", y
        if y = true
            EqualString Z$, "wfon", y
            if y = true
                ; the previous marker was also a waveform onset marker, so
                ; delete this one and re-search

                DeleteMarker z
                goto defineSCR_removeUnmatchedWFONEvents_loop
            endif
        endif

        ; if we get here we didn't delete the marker, so move on to search for
        ; the next marker

        Z$ = Y$
        i = z
        goto defineSCR_removeUnmatchedWFONEvents_loop
    endif
endif

; [ed] 12/22/10 Locate the final wfon event to define the last wfof event as
; the final event will not be the starting endpoint of a wfon pair. Bug #14796

i = 0
SearchForMarker "wfon", A, ( i + 1 ), z
defineSCR_findLastWfon_loop:
if z > 0
    i = z
    SearchForMarker "wfon", A, ( i + 1 ), z
    if z <> 0
        ; we still have more waveform onset events in the graph. Keep searching

        goto defineSCR_findLastWfon_loop
    else
        ; we found the last waveform on event at index i. Find the next
        ; negative crossing in B, if available, and place a wfof event
        ; there

        ; figure length of channel in seconds, store channel sample interval
        ; in y

        Get Channel Divider B, z
        Get SampleTime y
        y = ( z * y ) / 1000
        Get Channel Length B, z
        z = z * y

        ; get marker time and iterate forward each sample until we drop under
        ; zero

        Get Marker Time i, x
        Select Wave B

```

2

Figure A.143. Acqknowledge Scripting – #13 DefineSCREvents (pg 2/5)

```

defineSCR_findLastWfon_loop_2:
    if x < z
        Set HCursor x, x
        if Value <= 0
            ; we found our final zero crossing location so define the
            ; waveform offset event here

            InsertMarker "", A, "wfof"

        else
            ; move onto next sample position and continue searching

            x = x + y
            goto defineSCR_findLastWfon_loop_2
        endif
    endif

    ; check if we did insert a marker. If we didn't, there was no zero
    ; crossing after the final wfon event. Without a turning point we
    ; won't have a valid SCR, so remove the event

    if x >= z
        DeleteMarker i
    endif
endif

; SCR positions occur at the maximum value of phasic EDA inbetween our two
; threshold crossings. Configure a peak detector to both locate the SCR
; events and extract the maximum change.

Show Measurements
Get MeasurementRows r
Set MeasurementRows 1
Set Measurement 1, Max
Set MeasurementChannel 1, B
Array "scr_ampl" Clear

Transform FindPeak Cycle Event "wfon", A, StartNoLabel, "wfof", A, EndNoLabel
Transform FindPeak Selection Event StartEvent, 0, EndEvent, 0
Transform FindPeak Output Disable
Transform FindPeak Output Events Enable 1, "scr ", A, "", Max, A
Transform FindPeak Output Measurements EnableArray 0, "scr_ampl"
Set HCursor 0, 0
Transform FindPeak Execute All

; [ed] 10/28/08 Transformation cancel support
Transform IsCanceled q
if q = true
    Transform AsyncProgress Hide
    Halt
endif

; find the maximum SCR amplitude

m = 0
i = 0
Array "scr_ampl" Length, z
defineSCR_findMaxSCR_loop:
    ; [ed] 10/28/08 Transformation cancel support
    Transform IsCanceled q
    if q = true
        Transform AsyncProgress Hide
        Halt
    endif
    if i < z
        Array "scr_ampl" Get i, a
    
```

Figure A.144. Acqknowledge Scripting – #13 DefineSCREvents (pg 3/5)

```

        if a > m
            m = a
        endif
        i = i + 1
        goto defineSCR_findMaxSCR_loop
    endif

; compute our threshold level for valid SCRs

t = m * ( I / 100 )

; run through and reject SCRs underneath our threshold. We assume all "scr "
; events on the tonic EDA channel have been erased prior to this classification.
; At this point, therefore, the number of elements in the "scr_ampl" array
; matches the number and order of SCR events we placed on the channel during
; our final peak detection.
;
; By looping in reverse, we can delete events from the end and maintain the
; matching of array index with event index on the tonic EDA channel and avoid
; having to shift our array over

Array "scr_ampl" Length, z
i = z - 1
defineSCR_removeInvalidSCR_loop:
if i >= 0
    ; [ed] 10/28/08 Transformation cancel support
    Transform IsCanceled q
    if q = true
        Transform AsyncProgress Hide
        Halt
    endif

    ; check our threshold

    Array "scr_ampl" Get i, z
    if z < t
        ; the max amplitude of this scr was underneath our threshold, so
        ; we need to remove it.

        ; first find the marker. We'll use n as our marker index, starting at 1.
        ; To get the corresponding SCR event, we need to perform i + 1 searches
        ; for the SCR peak, waveform onset, and waveform offset events

        j = i
        n = 0
defineSCR_findIndexedSCR_loop:
        ; [ed] 10/28/08 Transformation cancel support
        Transform IsCanceled q
        if q = true
            Transform AsyncProgress Hide
            Halt
        endif
        SearchForMarker "scr ", A, ( n + 1 ), n
        if j > 0
            j = j - 1
            goto defineSCR_findIndexedSCR_loop
        endif

        ; remove SCR peak event

        DeleteMarker n

        ; find waveform onset event for the SCR

        j = i
        n = 0
defineSCR_findIndexedWFON_loop:

```

A

Figure A.145. Acqknowledge Scripting – #13 DefineSCREvents (pg 4/5)



```

; [ed] 10/28/08 Transformation cancel support
Transform IsCanceled q
if q = true
    Transform AsyncProgress Hide
    Halt
endif
SearchForMarker "wfon", A, ( n + 1 ), n
if j > 0
    j = j - 1
    goto defineSCR_findIndexedWFON_loop
endif

; remove the invalid waveform onset

DeleteMarker n

; find waveform end event for the SCR

j = i
n = 0
defineSCR_findIndexedWFOF_loop:
; [ed] 10/28/08 Transformation cancel support
Transform IsCanceled q
if q = true
    Transform AsyncProgress Hide
    Halt
endif
SearchForMarker "wfof", A, ( n + 1 ), n
if j > 0
    j = j - 1
    goto defineSCR_findIndexedWFOF_loop
endif

; remove the invalid waveform end

DeleteMarker n
endif

; examine the next previous SCR level

i = i - 1
goto defineSCR_removeInvalidSCR_loop
endif

; cleanup peak detector output and arrays

Array "scr_ampl" Clear
Transform FindPeak Output Disable
Set MeasurementRows r

Transform AsyncProgress Hide

SearchForMarker "scr ", A, 1, a
; if a = 0
;     Prompt "No SCRs were found! Please adjust the SCR threshold level in the Preferences and try again.", "OK", "", "", a
;     Set HCursor p, q
;     Update All
;     Halt
; endif

Set HCursor p, q
Autoscale
Update MMTs
Update All

```

Figure A.146. Acqknowledge Scripting – #13 DefineSCREvents (pg 5/5)

```
; REMOVE WAVE ONSETS
Get Marker Count c

loop:
  c = c - 1
  Get Marker Type c, X@
  if X@="wfon"
    DeleteMarker c
  endif
  if X@="wfof"
    DeleteMarker c
  endif

  if c = 0
    goto debugEnd
  else
    goto loop
  endif
debugEnd:
End
```

*Figure A.147. Acqknowledge Scripting – #14 RemoveOnsets (pg 1/1)*

```

; DETERMINE RR INTERVAL CHANNEL
Get NumChannels a
i = 0
FindChannel:
    Get Channel Name i, A@

    if i > a
        Halt
    else
        if A@ = "Phasic EDA (CH 2)"
            c = i
            Goto ChannelFound
        else
            i = i + 1
            Goto FindChannel
        endif
    endif
ChannelFound:

; Get number of channels
; Set i as 0 for loop
; Loop to find channel with text "RR Interval"
; Get channel label from channel index i

; If i is greater than the number of channels
; If not found then Halt macro
; otherwise
; Check channel name
; if correct channel then set C as the channel
; End loop
; otherwise
; look at next channel
; repeat loop
; done
; done
; end loop as channel found

Get FreeChannelIndex f

; Get new free / destination channel and call

Set HCursor 0,0
set measurement 1, MAX
set measurement 2, NONE
set measurement 3, NONE
set measurement 4, NONE
set measurement 5, NONE
set measurementchannel 1, c
get measurementXML U$
Set MeasurementXML U$

; Set Hcursor to start
; Set measurement 1 to Mean
; Set measurement 2 to none
; Set measurement 3 to none
; Set measurement 4 to none
; Set measurement 5 to none
; Set measurement channel to C using measure 1
; gets all the above
; sets all the above

Transform FindPeak Cycle Event "usr1", -1, startNoLabel, "usr1", -1, EndNoLabel
Transform FindPeak Selection Event StartEvent, 1, StartEvent, 6
Transform FindPeak Output Disable
Transform FindPeak Output Measurements DisableJournal
Transform FindPeak Output Measurements EnableWave
Transform FindPeak Execute All

; Taking the 3s before each stimuli
; ""
; Disable output
; and journal
; pasting the result to a wave
; executing all to wave F

Set Channel f, Label, "PhasicEDA"

End

```

Figure A.148. Acqknowledge Scripting – #15 PhasicMethod (pg 1/1)

```

Get Marker Count p
p = p - 1
Get Marker Sample p, q
Get Marker time p, o
Set HCursor o,o
InsertMarker "TEMP" -1, "usr1"

W = 2
Set HCursor 0,0

Get FreeChannelIndex w ; Get new free / desination channel and call

Select wave W
edit duplicate
Select wave w
Set Channel w, Label, "EDA"

Get FreeChannelIndex a ; Get new free / desination channel and call

Set HCursor 0,0 ; Set Hcursor to start
set measurement 1, Max ; Set measurement 1 to Mean
set measurement 2, NONE ; Set meaasurement 2 to none
set measurement 3, NONE ; Set meaasurement 3 to none
set measurement 4, NONE ; Set meaasurement 4 to none
set measurement 5, NONE ; Set meaasurement 5 to none
set measurementchannel 1, w ; Set meaasurement channel to C using measure 1
get measurementXML U$ ; gets all the above
Set MeasurementXML U$ ; sets all the above

Transform FindPeak Cycle Event "scr", w, startNoLabel, "scr", w, EndNoLabel, SingleEvent ; Taking the 3s before each ;
Transform FindPeak Selection Event StartEvent, 0-0.5, Endevent, 0+0.5 ; ""
Transform FindPeak Output Disable ; Disable output
Transform FindPeak Output Measurements DisableJournal ; and journal
Transform FindPeak Output Measurements EnableWave ; pasting the result to a wave
Transform FindPeak Execute All ; executing all to wave F

Get FreeChannelIndex b ; Get new free / desination channel and call
Select wave a
edit duplicate
edit remove
Set Channel b, Label, "SCRPeak"

Get FreeChannelIndex c ; Get new free / desination channel and call

Set HCursor 0,0 ; Set Hcursor to start
set measurement 1, Min ; Set measurement 1 to Mean
set measurement 2, NONE ; Set meaasurement 2 to none
set measurement 3, NONE ; Set meaasurement 3 to none
set measurement 4, NONE ; Set meaasurement 4 to none
set measurement 5, NONE ; Set meaasurement 5 to none
set measurementchannel 1, W ; Set meaasurement channel to C using mea
get measurementXML U$ ; gets all the above
Set MeasurementXML U$ ; sets all the above

Transform FindPeak Cycle Event "flag", w, startNoLabel, "flag", w, EndNoLabel, SingleEvent ; Taking the 3s before each ;
Transform FindPeak Selection Event StartEvent, 0-0.5, Endevent, 0+0.5 ; ""
Transform FindPeak Output Disable ; Disable output
Transform FindPeak Output Measurements DisableJournal ; and journal
Transform FindPeak Output Measurements EnableWave ; pasting the result to a wave
Transform FindPeak Execute All ; executing all to wave F

Get FreeChannelIndex d ; Get new free / desination channel and call
Select wave c
edit duplicate
edit remove

```

Figure A.149. Acqknowledge Scripting – #16 ManualEDAv2 (pg 1/4)

```

Set Channel d, Label, "SCROnset"

Get FreeChannelIndex e                                ; Get new free / desination channel and call

Set HCursor 0,0                                       ; Set Hcursor to start
set measurement 1, Max                                ; Set measurement 1 to Mean
set measurement 2, NONE                                ; Set meaasurement 2 to none
set measurement 3, NONE                                ; Set meaasurement 3 to none
set measurement 4, NONE                                ; Set meaasurement 4 to none
set measurement 5, NONE                                ; Set meaasurement 5 to none
set measurementchannel 1, b                            ; Set meaasurement channel to C using measure 1
get measurementXML U$                                  ; gets all the above
Set MeasurementXML U$                                  ; sets all the above

Transform FindPeak Cycle Event "usr1", -1, startNoLabel, "usr1", -1, EndNoLabel ; Taking the 3s before each stimuli
Transform FindPeak Selection Event StartEvent, 0, Endevent, 0 ; ""
Transform FindPeak Output Disable                    ; Disable output
Transform FindPeak Output Measurements DisableJournal ; and journal
Transform FindPeak Output Measurements EnableWave    ; pasting the result to a wave
Transform FindPeak Execute All

Get FreeChannelIndex f                                ; Get new free / desination channel and call
Select wave e
edit duplicate
edit remove
Set Channel f, Label, "SCRPeak"
Select wave b
edit remove

Get FreeChannelIndex g                                ; Get new free / desination channel and call

Set HCursor 0,0                                       ; Set Hcursor to start
set measurement 1, Max                                ; Set measurement 1 to Mean
set measurement 2, NONE                                ; Set meaasurement 2 to none
set measurement 3, NONE                                ; Set meaasurement 3 to none
set measurement 4, NONE                                ; Set meaasurement 4 to none
set measurement 5, NONE                                ; Set meaasurement 5 to none
set measurementchannel 1, d                            ; Set meaasurement channel to C using measure 1
get measurementXML U$                                  ; gets all the above
Set MeasurementXML U$                                  ; sets all the above

Transform FindPeak Cycle Event "usr1", -1, startNoLabel, "usr1", -1, EndNoLabel ; Taking the 3s before each stimuli
Transform FindPeak Selection Event StartEvent, 0-1, Endevent, 0-1 ; ""
Transform FindPeak Output Disable                    ; Disable output
Transform FindPeak Output Measurements DisableJournal ; and journal
Transform FindPeak Output Measurements EnableWave    ; pasting the result to a wave
Transform FindPeak Execute All                        ; executing all to wave F

Get FreeChannelIndex h                                ; Get new free / desination channel and call
Select wave g
edit duplicate
edit remove
Set Channel h, Label, "SCROnset"
Select wave d
edit remove

H@ = STR$(h, 0)                                       ; convert channel index to string character (
H@ = LTRIM$(H@)                                       ; remove the blank space at the start
F@ = STR$(f, 0)                                       ; convert channel index to string character (
F@ = LTRIM$(F@)                                       ; remove the blank space at the start

C@ = "CH" + F@
C@ = C@ + "-CH"
C@ = C@ + H@

```

Figure A.150. Acqknowledge Scripting – #16 ManualEDAv2 (pg 2/4)

```

Get FreeChannelIndex j                               ; Get new free / desination channel and call
Select wave h
edit duplicate

Set Hcursor 0,0
Select Wave j
edit selectall
Transform AsyncProgress Show
Transform Expression C@
Transform AsyncProgress hide
Set Channel j, Label, "EDADiff"
Select wave h
edit remove
Select wave f
edit remove
Select wave w
edit remove

Get FreeChannelIndex z                               ; Get new free / desination channel and call
Select wave j
edit duplicate
edit remove
Set Channel z, Label, "Temp"

Get FreeChannelIndex y                               ; Get new free / desination channel and call

Set HCursor 0,0                                       ; Set Hcursor to start
set measurement 1, Value                             ; Set measurement 1 to Mean
set measurement 2, NONE                               ; Set meaasurement 2 to none
set measurement 3, NONE                               ; Set meaasurement 3 to none
set measurement 4, NONE                               ; Set meaasurement 4 to none
set measurement 5, NONE                               ; Set meaasurement 5 to none
set measurementchannel 1, z                           ; Set meaasurement channel to C using measure 1
get measurementXML U$                                ; gets all the above
Set MeasurementXML U$                                ; sets all the above

Transform FindPeak Cycle Event "usr1", -1, startNoLabel, "usr1", -1, EndNoLabel , SingleEvent ; Taking the 3s before each stimuli
Transform FindPeak Selection Event StartEvent, 0+2, StartEvent, 0+2 ; ""
Transform FindPeak Output Disable                    ; Disable output
Transform FindPeak Output Measurements DisableJournal ; and journal
Transform FindPeak Output Measurements EnableWave    ; pasting the result to a wave
Transform FindPeak Execute All

Get FreeChannelIndex x                               ; Get new free / desination channel and call
Select wave y
edit duplicate
edit remove
Set Channel x, Label, "Peaks"
Select wave z
edit remove

Get FreeChannelIndex v                               ; Get new free / desination channel and call

Set HCursor 0,0                                       ; Set Hcursor to start
set measurement 1, Max                                ; Set measurement 1 to Mean
set measurement 2, NONE                               ; Set meaasurement 2 to none
set measurement 3, NONE                               ; Set meaasurement 3 to none

```

Figure A.151. Acqknowledge Scripting – #16 ManualEDAv2 (pg 3/4)

```

set measurement 4, NONE                ; Set meaasurement 4 to none
set measurement 5, NONE                ; Set meaasurement 5 to none
set measurementchannel 1, x            ; Set meaasurement channel to C using measure 1
get measurementXML U$                  ; gets all the above
Set MeasurementXML U$                  ; sets all the above

Transform FindPeak Cycle Event "usr1", -1, startNoLabel, "usr1", -1, EndNoLabel ; Taking the 3s before each stimuli
Transform FindPeak Selection Event StartEvent, 0, Endevent, 0                ; ""
Transform FindPeak Output Disable                                           ; Disable output
Transform FindPeak Output Measurements DisableJournal                      ; and journal
Transform FindPeak Output Measurements EnableWave                          ; pasting the result to a wave
Transform FindPeak Execute All                                              ; executing all to wave F

Get FreeChannelIndex u                                                       ; Get new free / desination channel and call
Select wave v
edit duplicate
edit remove
Set Channel u, Label, "EDADiff"
Select wave x
edit remove

; DELETE TEMP marker added just to cover last trial
Set HCursor 0,0                                                             ; Set Hcurser to start of grap
Get Marker Count n                                                           ; Get the number of markers

MarkerDeleteloop:                                                            ; Loop through each marker

    Get Marker Text n, T@                                                    ; Get the marker text and as
    if T@ = "TEMP"                                                            ; Check the marker text
        DeleteMarker n                                                        ; if Question then delete
    endif                                                                    ; Done

    if n = 0                                                                    ; If we've done all the marke
        goto MarkerDeleteEnd                                                  ; ""
    else                                                                    ; OR
        n = n - 1                                                            ; Next marker
        goto MarkerDeleteloop                                                ; Repeat loop
    endif                                                                    ; ""

MarkerDeleteEnd:

End

```

Figure A.152. Acqknowledge Scripting – #16 ManualEDAv2 (pg 4/4)

```
Select Wave 6
Edit remove
Select Wave 7
Edit remove

Call "RRInterval"
Call "HRFunctionv2"

Select Wave 8
Edit remove

Select Wave 7
edit Duplicate
Edit remove

Set Channel 6, Label, "1sHR"

Call "1sEDA"
Call "1sEDAOUT"
Call "1sHROUT"
End
```

*Figure A.153. Acqknowledge Scripting – #17 1sHR (pg 1/1)*



```

R$ = ""
set measurement 1, Value
set measurement 2, Value
set measurement 3, NONE
set measurement 4, NONE
set measurement 5, NONE
set measurementchannel 1, 3
set measurementchannel 2, 6
Set HCursor 0,0
Get Title R$
K$ = "C:\Users\danni\Desktop\OUT" + R$
K$ = K$ + "_HR.xls"

stringarray "Items" clear
stringarray "Title" clear

array "1s-1" clear
array "1s0" clear
array "1s1" clear
array "1s2" clear
array "1s3" clear
array "1s4" clear
array "1s5" clear
array "1s6" clear
array "1s7" clear
array "1s8" clear
array "1s9" clear
array "1s10" clear
array "1s11" clear
array "1s12" clear
array "1s13" clear
array "1s14" clear
array "1s15" clear

Get marker count S

s = 1
i = 0

BuildArrays:

    Get Marker Type s, X$

    if X$ = "usr1"
        Get Marker Text s, T$
        stringarray "Items" Set i, T$

        Get Marker Time s, T
        z = 0
        miniloop:
            if (s + z) < S
                Get Marker Time s+z, e
                Get marker text s+z, Q$

                if Q$ = "usr1"
                    else
                        z = z + 1
                        goto miniloop
                    endif
            else
                get marker Time S, e
            endif

            ;Mean of channel
            T = T + 2

```

Figure A.154. Acqknowledge Scripting – #19 1sHROUTPUT (pg 1/6)

```

set hcursor T,T
stringarray "Title" Set i, R$

T = T - 2
;1sec of channel

T = T - 0.01
set hcursor T,T
Update MMTs
Get MeasurementValue 2, Y
array "1s-1" Set i, Y

T = T + 0.5
set hcursor T,T
Update MMTs
Get MeasurementValue 2, Y
array "1s0" Set i, Y

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s1" Set i, Y
else
    goto End1secArr
endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s2" Set i, Y
else
    goto End1secArr
endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s3" Set i, Y
else
    goto End1secArr
endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s4" Set i, Y
else
    goto End1secArr
endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s5" Set i, Y
else
    goto End1secArr
endif

```

Figure A.155. Acqknowledge Scripting – #19 1sHROUTPUT (pg 2/6)

```

endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s6" Set i, Y
else
    goto End1secArr
endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s7" Set i, Y
else
    goto End1secArr
endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s8" Set i, Y
else
    goto End1secArr
endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s9" Set i, Y
else
    goto End1secArr
endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s10" Set i, Y
else
    goto End1secArr
endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y
    array "1s11" Set i, Y
else
    goto End1secArr
endif

if T < e
    T = T + 1
    set hcursor T,T
    Update MMTs
    Get MeasurementValue 2, Y

```

*Figure A.156. Acqknowledge Scripting – #19 1sHROUTPUT (pg 3/6)*

```

        array "1s12" Set i, Y
    else
        goto End1secArr
    endif

    if T < e
        T = T + 1
        set hcursor T,T
        Update MMTs
        Get MeasurementValue 2, Y
        array "1s13" Set i, Y
    else
        goto End1secArr
    endif

    if T < e
        T = T + 1
        set hcursor T,T
        Update MMTs
        Get MeasurementValue 2, Y
        array "1s14" Set i, Y
    else
        goto End1secArr
    endif

    if T < e
        T = T + 1
        set hcursor T,T
        Update MMTs
        Get MeasurementValue 2, Y
        array "1s15" Set i, Y
    else
        goto End1secArr
    endif

    End1secArr:

    i = i + 1

endif

if s = S
    goto EndBuildArrays
else
    s = s + 1
    goto BuildArrays
endif

EndBuildArrays:

v = 0
stringArray "Items" length, x
ExcelSpreadsheet "_out" New

collate:

if v < x
    ;Tiltes
    ExcelSpreadsheet "_out" SetCellText, 0, 0, "Title"
    ExcelSpreadsheet "_out" SetCellText, 0, 1, "Item"
    ExcelSpreadsheet "_out" SetCellText, 0, 2, "1s-1"
    ExcelSpreadsheet "_out" SetCellText, 0, 3, "1s0"
    ExcelSpreadsheet "_out" SetCellText, 0, 4, "1s1"
    ExcelSpreadsheet "_out" SetCellText, 0, 5, "1s2"
    ExcelSpreadsheet "_out" SetCellText, 0, 6, "1s3"
    ExcelSpreadsheet "_out" SetCellText, 0, 7, "1s4"

```

Figure A.157. Acqknowledge Scripting – #19 1sHROUTPUT (pg 4/6)

```

ExcelSpreadsheet "_out" SetCellText, 0, 8, "1s5"
ExcelSpreadsheet "_out" SetCellText, 0, 9, "1s6"
ExcelSpreadsheet "_out" SetCellText, 0, 10, "1s7"
ExcelSpreadsheet "_out" SetCellText, 0, 11, "1s8"
ExcelSpreadsheet "_out" SetCellText, 0, 12, "1s9"
ExcelSpreadsheet "_out" SetCellText, 0, 13, "1s10"
ExcelSpreadsheet "_out" SetCellText, 0, 14, "1s11"
ExcelSpreadsheet "_out" SetCellText, 0, 15, "1s12"
ExcelSpreadsheet "_out" SetCellText, 0, 16, "1s13"
ExcelSpreadsheet "_out" SetCellText, 0, 17, "1s14"
ExcelSpreadsheet "_out" SetCellText, 0, 18, "1s15"

;get stuff from arrays
StringArray "Title" get, v, R$
StringArray "Items" get, v, V$
Array "1s-1" get, v, b
Array "1s0" get, v, c
Array "1s1" get, v, d
Array "1s2" get, v, e
Array "1s3" get, v, f
Array "1s4" get, v, g
Array "1s5" get, v, h
Array "1s6" get, v, i
Array "1s7" get, v, j
Array "1s8" get, v, k
Array "1s9" get, v, l
Array "1s10" get, v, m
Array "1s11" get, v, n
Array "1s12" get, v, o
Array "1s13" get, v, p
Array "1s14" get, v, q
Array "1s15" get, v, r

;output ti excel
ExcelSpreadsheet "_out" SetCellText, (v + 1), 0, R$
ExcelSpreadsheet "_out" SetCellText, (v + 1), 1, V$
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 2, b
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 3, c
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 4, d
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 5, e
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 6, f
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 7, g
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 8, h
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 9, i
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 10, j
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 11, k
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 12, l
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 13, m
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 14, n
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 15, o
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 16, p
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 17, q
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 18, r

v = v + 1
goto collate

endif

ExcelSpreadsheet "_out" SaveToFile, K$, SaveOnly
ExcelSpreadsheet "_out" Delete

stringarray "Items" clear
stringarray "Title" clear

array "1s-1" clear
array "1s0" clear

```

Figure A.58. Acqknowledge Scripting – #19 1sHROUTPUT (pg 5/6)

```
array "1s1" clear  
array "1s2" clear  
array "1s3" clear  
array "1s4" clear  
array "1s5" clear  
array "1s6" clear  
array "1s7" clear  
array "1s8" clear  
array "1s9" clear  
array "1s10" clear  
array "1s11" clear  
array "1s12" clear  
array "1s13" clear  
array "1s14" clear  
array "1s15" clear  
  
End
```

*Figure A.159. Acqknowledge Scripting – #19 1sHROUTPUT (pg 6/6)*

```

; EXPORT VALUES FROM GRAPH

; SET UP ARRAYS (MAX 15 OUTPUTS WITH FIRST 3 ALWAYS GRAPH, ITEMS, ITEM TIME)
StringArray "ChannelNames" Clear
Array "SelectedChannels" Clear
StringArray "SelectedChannelNames" Clear
StringArray "Item" Clear
Array "Itemtime" Clear
Array "Column4" Clear
Array "Column5" Clear
Array "Column6" Clear
Array "Column7" Clear
Array "Column8" Clear
Array "Column9" Clear
Array "Column10" Clear
Array "Column11" Clear
Array "Column12" Clear
Array "Column13" Clear
Array "Column14" Clear
Array "Column15" Clear
Array "Column16" Clear
Array "Column17" Clear
Array "Column18" Clear

; GET GRAPH TITLE
Get Title R@
GetStringLength R@ p
R@ = Left$(R@,p-4)

; SET DEFAULT SAVE IF NOT SPECIFIED

;ChooseDirectoryPrompt "Output Location" B$ E
;K$ = "C:\Users\Daniel Gunnell\Desktop\test_" + R@
;ChooseMultipleChannels "CSV Out", "Choose Channels to Extract (Max 15)", "Select", "ChannelSelection" ; ASK FOR CHANN

B$ = "C:\Users\danni\Desktop"

Array "ChannelSelection" Set 1, 0
Array "ChannelSelection" Set 2, 0
Array "ChannelSelection" Set 3, 1
Array "ChannelSelection" Set 4, 1
Array "ChannelSelection" Set 5, 0

; BUILD ARRAY OF CHANNEL NAMES
i = 0
BuildChannelNamesArray:
  Get Channel Name i, L@
  StringArray "ChannelNames" Set i, L@
  i = i + 1
  if i > 59
    Goto Built
  else
    Goto BuildChannelNamesArray
  endif
Built:

; BUILD ARRAY OF SELECTED CHANNEL NAMES
i = 0
SelectedChannelNames:
  Array "ChannelSelection" Get i, z
  if z = 1
    StringArray "ChannelNames" Get i, K@
    StringArray "SelectedChannelNames" Set j, K@
    j = j + 1
  endif
  i = i + 1
  if i > 59

```

Figure A.160. Acqknowledge Scripting – #26 ExportExcel (pg 1/4)

```

        Goto Finished
    else
        Goto SelectedChannelNames
    endif
Finished:

; SET THIS FOR REST OF MACRO TO INDICATE NUMBER OF OUTPUT CHANNELS DECIDED
J = j

; BUILD ARRAY OF SELECTED CHANNEL NUMBERS
j = 0
i = 0
CheckSelectedChannels:
    Array "ChannelSelection" Get i, z
    if z = 1
        Array "SelectedChannels" Set j, i
        j = j + 1
    endif
    i = i + 1
    if i > 59
        Goto Checked
    else
        Goto CheckSelectedChannels
    endif
Checked:

; SET MEASUREMENTS
set measurement 1, Value
set measurement 2, None
set measurement 3, None
set measurement 4, None
set measurement 5, None

; DETERMINE NUMBER OF USR1 MARKERS
Get marker Count f
w = 1
g = 0
CountUsr1:
    get marker type w, X@
    if X@ = "usr1"
        Get Marker Text w, T@
        If T@ = "EndCIT"
        else
            g = g + 1
        endif
    endif
    w = w + 1
    if w > f
        goto Counted
    else
        goto CountUsr1
    endif
Counted:

; MAKE EDA ARRAY

; BUILD EACH ARRAY AND INSERT DATA FROM MEASUREMENT VALUES

x = 1 ; Marker index
v = 0 ; Array index

BuildArrays:

    Get Marker Type x, X@ ; Find first marker index = 1

```

Figure A.161. Acqknowledge Scripting – #26 ExportExcel (pg 2/4)



```

if X@ = "usr1"
    Get Marker Text x, T@

    If T@ = "EndCIT"
        ; If its EndCIT then ignore

    else
        ; otherwise
        stringarray "Item" Set v, T@
        ; Set StringArray Items to equal the marker
        Get Marker Time x, t
        ; Set the time of that marker
        Array "Itemtime" Set v, t
        ; Set the Array Itemtime to equal the marker
        t = t + 2
        ; add 2 to the marker time as this is where 1

        set hcursor t,t

        q = 0
        LoopEachArray:

            Array "SelectedChannels" Get q, h
            set measurementchannel 1, h
            Update MMTs
            Get MeasurementValue 1, s

            P@ = STR$((q + 4), 0)
            P@ = LTRIM$(P@)
            S@ = "Column" + P@

            array S@ Set v, s

            if q + 1 = J
                goto Done
            else
                q = q + 1
                Goto LoopEachArray
            endif

        Done:

        v = v + 1

    endif

endif

x = x + 1

if x > f
    goto EndBuildArrays
else
    goto BuildArrays
endif

EndBuildArrays:

; EXCEL OUTPUT FROM BUILT ARRAYS

v = 0
stringArray "Item" length, x
ExcelSpreadsheet "_out" New

collate:

;Tiltes
ExcelSpreadsheet "_out" SetCellText, 0, 0, "Graph"
ExcelSpreadsheet "_out" SetCellText, 0, 1, "Item"
ExcelSpreadsheet "_out" SetCellText, 0, 2, "Itemtime"

o = 3

```

Figure A.162. Acqknowledge Scripting – #26 ExportExcel (pg 3/4)

```

i = 0
TitleLoop:
    StringArray "SelectedChannelNames" Get i, O@
    ExcelSpreadsheet "_out" SetCellText, 0, o, O@
    i = i + 1
    o = o + 1
    if i = J
        goto TitlesDone
    else
        goto titleLoop
    endif
TitlesDone:
;Titles done

if v < x

;get stuff from arrays
StringArray "Item" Get v, V@
Array "Itemtime" Get v, a

;Columns 1-3
ExcelSpreadsheet "_out" SetCellText, (v + 1), 0, R@
ExcelSpreadsheet "_out" SetCellText, (v + 1), 1, V@
ExcelSpreadsheet "_out" SetCellValue, (v + 1), 2, a

q = 3
; Columns 4-n
LoopEachArray2:
    P@ = STR$((q + 1), 0)
    P@ = LTRIM$(P@)
    S@ = "Column" + P@

    array S@ Get v, b
    ExcelSpreadsheet "_out" SetCellValue, (v + 1), q, b

    if q - 2 = J
        goto Done2
    else
        q = q + 1
        Goto LoopEachArray2
    endif
Done2:

v = v + 1
goto collate

endif

N$ = B$ + "\Out_"
N$ = N$ + R@
N$ = N$ + ".xls"
ExcelSpreadsheet "_out" SaveToFile, N$, SaveOnly
ExcelSpreadsheet "_out" Delete

StringArray "ChannelNames" Clear
Array "SelectedChannels" Clear
StringArray "SelectedChannelNames" Clear
StringArray "Item" Clear
Array "Itemtime" Clear
Array "Column4" Clear
Array "Column5" Clear
Array "Column6" Clear
Array "Column7" Clear
Array "Column8" Clear
Array "Column9" Clear

```

Figure A.163. Acqknowledge Scripting – #26 ExportExcel (pg 4/4)

```

;
;
; OnOpenFile
;
;
;
; This BIOPAC Basic script shows an example of how to perform batch file
; conversion. It illustrates basic user prompts, listing directory contents,
; loops, and file export.

;
;
; Display an informational prompt to the user describing the example
;
;
Prompt "This example script exports all graph files within a directory to text format.", "Run", "Cancel", "", a
if a = 2
    ; cancel button pressed
    Halt
endif

;
; Prompt the user to choose a directory
;
ChooseDirectoryPrompt "Convert graph files in which directory?", A$, z
if z = 1
    ; User clicked cancel in the dialog, so stop macro execution
    Halt
endif

;
; Get the file listing in the directory. This extracts the list out
; into a string array
;
ListDirectoryContents A$, Files, " _"

;
; Change our working directory to the directory where the graphs are
; located. This will allow us to open and export the files without
; needing to construct absolute paths.
;
Set Folder Path A$

;
; Loop over the files in the directory, searching for those that end
; in .acq extensions and export them. As BIOPAC Basic does not have any
; explicit loop constructs, we use a combination an if construct and a
; label and goto.
;
; we'll use an asynchronous progress dialog to allow the user to cancel
; during the export process
Transform AsyncProgress Show
Transform AsyncProgress SetMessage "Exporting..."

i = 0
filesLoop:

```

*Figure A.164. Acqknowledge Scripting – #27 TextExport (pg 1/4)*

```

        Transform AsyncProgress Show
        i = i + 1
        goto filesLoop
    endif

    ; User chose to replace the file, so remove it

    Delete Y$

    ; restore the progress message visibility

    Transform AsyncProgress Show
    Transform AsyncProgress SetMessage X$
endif

;
; check to see if the graph is already open. If so, just export that
; window. Each graph file should only be opened once. If the same
; file is opened multiple times, the application may not be able
; to exit properly or re-open the graph file.
;

GetGraphList "_graphs"
StringArray "_graphs" Length, a
b = 0
graphLoop:
    if b < a
        ;
        ; get the next graph title out of our array
        ;

        StringArray "_graphs" Get b, M$
        EqualString M$, Z$, c
        if c = 1
            ;
            ; We found that the graph was already open!
            ;

            ;
            ; Make the newly opened graph our active target graph for
            ; macro commands
            ;

            Select Window Z$

            ;
            ; Export the graph as a text file
            ;

            ExportGraphData Y$, Text, NoHeader, NoTime, Tab, PCLineEnding, z
        else
            ;
            ; we did not match the graph title. Continue searching the
            ; titles of remaining graphs.
            ;

            b = b + 1
            goto graphLoop
        endif
    endif

    if a = b
        ;
        ; graph is not open. open up the graph file
        ;

```

Figure A.165. Acqknowledge Scripting – #27 TextExport (pg 2/4)

```

StringArray "" Length, z
if i < z
    ; check if the user has canceled the export

    Transform IsCanceled a
    if a = 1
        ; user requested a cancel. Dismiss our progress dialog and
        ; halt macro execution

        Transform AsyncProgress Hide
        Halt
    endif

    ; get the filename we should process

    StringArray "" Get i, Z$

    ; check if the filename is long enough. If not, continue onto the
    ; next file

    GetStringLength Z$, z
    if z < 5
        ; move to next loop iteration

        i = i + 1
        goto filesLoop
    endif

    ; get the extension of the file and check if it is a graph file

    Y$ = RIGHT$(Z$, 4)
    StrICmp Y$, ".acq", z ; performs case-insensitive comparison for Win32 filesystems
    if z = 0
        ;
        ; we found our extension, so we have a graph file. Revise our progress message
        ;
        X$ = "Exporting \" + Z$
        X$ = X$ + "\"..."

        Transform AsyncProgress SetMessage X$

        ;
        ; construct the name of the text file that we'll export from the
        ; basename of the graph and a .txt extension
        ;

        GetStringLength Z$, y
        Y$ = LEFT$(Z$, ( y - 4 ) )
        Y$ = Y$ + ".txt"

        ;
        ; check if the text file already exists on disk. If so, prompt
        ; the user to see if they want to delete it
        ;

        CheckFile Y$, z
        if z = 1
            Transform AsyncProgress Hide ; to make sure our prompt appears on top

            W$ = "The file \" + Y$
            W$ = W$ + "\" already exists on disk. Replace it?"

            Prompt W$, "Yes", "No", "", b
            if b = 2
                ; user does not want to replace the file, so skip onto processing
                ; the next file

```

Figure A.166. Acqknowledge Scripting – #27 TextExport (pg 3/4)

```

    Open Z$, a, A$
    if a = 1
        ;
        ; Make the newly opened graph our active target graph for
        ; macro commands
        ;

        Select Window Z$

        ;
        ; Export the graph as a text file
        ;
        ExportGraphData Y$, Text, Header, Time, Tab, PCLineEnding, a

        ;
        ; Close the graph now that it's been exported
        ;

        CloseGraph
    endif
endif

; increment to the next file in our array and continue our loop

i = i + 1
goto filesLoop
endif

;
; Dismiss the asynchronous progress dialog and display a prompt to the
; user that the export is complete.
;

Transform AsyncProgress Hide

Prompt "Export complete!", "OK"

End

```

*Figure A.167. Acqknowledge Scripting – #27 TextExport (pg 4/4)*

## **APPENDIX 3**

### **DATA**

## Processed Data

*Table A.1. Seen this Scene, Experiment 1 Data*

| <b>P</b> | <b>Age</b> | <b>Gender</b> | <b>Mean Reaction Times</b> |              | <b>Mean % Errors</b> |              |
|----------|------------|---------------|----------------------------|--------------|----------------------|--------------|
|          |            |               | <b>Control</b>             | <b>Crime</b> | <b>Control</b>       | <b>Crime</b> |
| 1        | 19         | F             | 449                        | 485          | 2                    | 0            |
| 2        | 19         | M             | 451                        | 496          | 2                    | 1            |
| 3        | 20         | F             | 382                        | 395          | 2                    | 0            |
| 4        | 20         | F             | 481                        | 512          | 2                    | 12           |
| 5        | 19         | M             | 463                        | 506          | 2                    | 3            |
| 6        | 20         | M             | 411                        | 424          | 0                    | 0            |
| 7        | 18         | F             | 463                        | 507          | 1                    | 0            |
| 8        | 21         | F             | 512                        | 530          | 16                   | 3            |
| 9        | 22         | F             | 410                        | 418          | 2                    | 3            |
| 10       | 20         | M             | 468                        | 507          | 4                    | 9            |
| 11       | 32         | F             | 450                        | 498          | 1                    | 1            |
| 12       | 19         | F             | 450                        | 508          | 0                    | 5            |
| 13       | 19         | F             | 414                        | 474          | 1                    | 0            |
| 14       | 19         | F             | 410                        | 429          | 1                    | 4            |
| 15       | 21         | F             | 423                        | 445          | 2                    | 3            |
| 16       | 20         | M             | 469                        | 528          | 3                    | 11           |
| 17       | 26         | M             | 448                        | 485          | 0                    | 3            |
| 18       | 20         | F             | 537                        | 579          | 9                    | 5            |
| 19       | 19         | M             | 490                        | 516          | 2                    | 3            |
| 20       | 23         | F             | 470                        | 495          | 1                    | 8            |
| 21       | 19         | F             | 460                        | 462          | 1                    | 0            |
| 22       | 18         | F             | 446                        | 483          | 0                    | 3            |
| 23       | 22         | F             | 405                        | 420          | 0                    | 0            |
| 24       | 27         | M             | 473                        | 473          | 1                    | 0            |
| 25       | 18         | M             | 423                        | 421          | 2                    | 0            |
| 26       | 19         | F             | 433                        | 464          | 1                    | 0            |
| 27       | 19         | F             | 479                        | 508          | 2                    | 9            |
| 28       | 20         | F             | 508                        | 521          | 2                    | 1            |
| 29       | 19         | F             | 494                        | 496          | 2                    | 3            |
| 30       | 20         | F             | 420                        | 444          | 0                    | 0            |
| 31       | 21         | M             | 484                        | 556          | 2                    | 1            |
| 32       | 19         | F             | 541                        | 550          | 2                    | 1            |
| 33       | 22         | F             | 495                        | 559          | 1                    | 12           |
| 34       | 19         | F             | 439                        | 488          | 0                    | 1            |
| 35       | 18         | M             | 532                        | 531          | 5                    | 1            |
| 36       | 20         | F             | 473                        | 500          | 1                    | 1            |



Table A.2. *Seen this Scene, Experiment 2 Data*

| P  | Age | Gender | Motivation | Stress | Innocence | Mean Reaction Times |       |         |       | Mean % Errors |       |         |       |
|----|-----|--------|------------|--------|-----------|---------------------|-------|---------|-------|---------------|-------|---------|-------|
|    |     |        |            |        |           | Object              |       | Scenes  |       | Object        |       | Scenes  |       |
|    |     |        |            |        |           | Control             | Crime | Control | Crime | Control       | Crime | Control | Crime |
| 1  | 19  | F      | 4          | 3      | 2         | 466                 | 449   | 462     | 478   | 4             | 3     | 2       | 0     |
| 2  | 18  | F      | 3          | 6      | 4         | 515                 | 540   | 528     | 538   | 6             | 20    | 3       | 7     |
| 3  | 18  | F      | 5          | 2      | 3         | 442                 | 465   | 449     | 486   | 1             | 0     | 0       | 0     |
| 4  | 19  | F      | 5          | 2      | 4         | 447                 | 482   | 461     | 535   | 3             | 7     | 1       | 3     |
| 5  | 19  | F      | 4          | 3      | 3         | 442                 | 433   | 475     | 479   | 3             | 7     | 0       | 3     |
| 6  | 19  | F      | 4          | 6      | 3         | 445                 | 422   | 458     | 456   | 1             | 0     | 0       | 0     |
| 7  | 19  | F      | 4          | 4      | 5         | 411                 | 422   | 437     | 438   | 1             | 0     | 0       | 3     |
| 8  | 19  | F      | 3          | 2      | 3         | 366                 | 373   | 394     | 402   | 1             | 0     | 2       | 3     |
| 9  | 18  | F      | 3          | 5      | 2         | 463                 | 464   | 499     | 472   | 7             | 3     | 5       | 3     |
| 10 | 19  | M      | 4          | 3      | 3         | 401                 | 443   | 402     | 435   | 1             | 0     | 0       | 0     |
| 11 | 19  | F      | 3          | 1      | 3         | 473                 | 528   | 487     | 482   | 2             | 3     | 1       | 0     |
| 12 | 18  | F      | 4          | 6      | 4         | 469                 | 540   | 462     | 478   | 3             | 10    | 0       | 0     |
| 13 | 20  | F      | 5          | 5      | 2         | 450                 | 521   | 498     | 523   | 3             | 33    | 4       | 50    |
| 14 | 19  | M      | 4          | 2      | 4         | 438                 | 524   | 446     | 486   | 9             | 3     | 0       | 3     |
| 15 | 20  | F      | 3          | 2      | 3         | 422                 | 433   | 421     | 445   | 8             | 17    | 14      | 8     |
| 16 | 19  | F      | 3          | 4      | 4         | 395                 | 426   | 404     | 413   | 1             | 0     | 0       | 0     |
| 17 | 18  | F      | 5          | 5      | 3         | 444                 | 404   | 434     | 458   | 6             | 7     | 2       | 7     |
| 18 | 19  | F      | 5          | 5      | 3         | 411                 | 396   | 436     | 482   | 1             | 0     | 2       | 7     |
| 19 | 21  | M      | 4          | 4      | 4         | 420                 | 446   | 403     | 424   | 0             | 0     | 1       | 0     |
| 20 | 18  | F      | 5          | 2      | 5         | 442                 | 476   | 435     | 423   | 2             | 0     | 1       | 0     |
| 21 | 19  | F      | 4          | 3      | 4         | 450                 | 488   | 476     | 580   | 4             | 0     | 2       | 13    |
| 22 | 18  | F      | 5          | 3      | 4         | 420                 | 522   | 453     | 466   | 1             | 7     | 1       | 0     |
| 23 | 18  | M      | 4          | 6      | 4         | 383                 | 403   | 409     | 408   | 0             | 0     | 2       | 7     |
| 24 | 18  | M      | 4          | 6      | 3         | 459                 | 435   | 475     | 558   | 3             | 0     | 6       | 13    |
| 25 | 18  | F      | 4          | 3      | 2         | 486                 | 523   | 534     | 554   | 3             | 0     | 3       | 10    |
| 26 | 20  | F      | 4          | 6      | 3         | 452                 | 385   | 489     | 488   | 12            | 33    | 19      | 23    |
| 27 | 19  | F      | 3          | 2      | 3         | 394                 | 383   | 460     | 446   | 3             | 3     | 3       | 3     |
| 28 | 18  | F      | 4          | 6      | 3         | 429                 | 410   | 428     | 435   | 0             | 7     | 2       | 0     |
| 29 | 19  | F      | 4          | 4      | 2         | 430                 | 499   | 444     | 450   | 3             | 0     | 0       | 3     |
| 30 | 19  | F      | 4          | 4      | 3         | 359                 | 353   | 385     | 405   | 2             | 0     | 6       | 3     |
| 31 | 19  | F      | 4          | 5      | 3         | 458                 | 490   | 475     | 540   | 2             | 7     | 1       | 3     |
| 32 | 19  | F      | 5          | 6      | 3         | 394                 | 411   | 401     | 420   | 3             | 10    | 0       | 0     |
| 33 | 19  | F      | 4          | 4      | 4         | 428                 | 429   | 458     | 473   | 6             | 10    | 0       | 3     |
| 34 | 18  | F      | 4          | 5      | 5         | 388                 | 425   | 395     | 444   | 1             | 7     | 4       | 0     |
| 35 | 19  | F      | 5          | 6      | 2         | 429                 | 433   | 436     | 447   | 5             | 0     | 1       | 0     |
| 36 | 19  | F      | 4          | 2      | 2         | 416                 | 475   | 412     | 473   | 1             | 0     | 1       | 0     |
| 37 | 18  | F      | 2          | 4      | 3         | 400                 | 389   | 416     | 383   | 1             | 0     | 0       | 0     |
| 38 | 21  | F      | 6          | 5      | 4         | 415                 | 458   | 433     | 440   | 5             | 13    | 2       | 7     |
| 39 | 18  | F      | 4          | 5      | 3         | 405                 | 455   | 423     | 510   | 1             | 3     | 0       | 3     |
| 40 | 18  | F      | 5          | 6      | 6         | 369                 | 412   | 390     | 400   | 2             | 0     | 2       | 3     |
| 41 | 19  | F      | 4          | 5      | 3         | 408                 | 428   | 448     | 438   | 4             | 0     | 4       | 3     |
| 42 | 18  | M      | 5          | 2      | 4         | 429                 | 444   | 438     | 422   | 1             | 0     | 2       | 0     |
| 43 | 19  | F      | 5          | 1      | 4         | 436                 | 452   | 436     | 430   | 2             | 3     | 2       | 10    |
| 44 | 18  | M      | 4          | 2      | 2         | 469                 | 484   | 466     | 451   | 0             | 0     | 1       | 3     |

Table A.3. *Seen this Scene, Experiment 3 Data*

| P  | Condition | Age | Gender | Mean Reaction Times |       | Mean % Errors |       |
|----|-----------|-----|--------|---------------------|-------|---------------|-------|
|    |           |     |        | Control             | Crime | Control       | Crime |
| 1  | Control   | 20  | F      | 432                 | 434   | 2             | 5     |
| 2  | Control   | 20  | M      | 406                 | 426   | 1             | 0     |
| 3  | Control   | 21  | F      | 431                 | 475   | 2             | 3     |
| 4  | Control   | 34  | F      | 458                 | 466   | 1             | 1     |
| 5  | Control   | 31  | F      | 472                 | 473   | 2             | 0     |
| 6  | Control   | 19  | M      | 529                 | 564   | 9             | 1     |
| 7  | Control   | 30  | F      | 444                 | 471   | 0             | 0     |
| 9  | Control   | 22  | M      | 498                 | 519   | 9             | 51    |
| 13 | Control   | 22  | F      | 459                 | 457   | 8             | 7     |
| 14 | Control   | 18  | F      | 510                 | 576   | 1             | 1     |
| 15 | Control   | 20  | F      | 414                 | 446   | 0             | 1     |
| 16 | Control   | 19  | F      | 462                 | 474   | 3             | 3     |
| 20 | Control   | 22  | M      | 435                 | 447   | 3             | 4     |
| 21 | Control   | 18  | M      | 453                 | 480   | 2             | 0     |
| 22 | Control   | 22  | F      | 355                 | 352   | 0             | 1     |
| 25 | Control   | 42  | F      | 415                 | 471   | 1             | 1     |
| 30 | Control   | 18  | M      | 535                 | 573   | 21            | 21    |
| 32 | Control   | 21  | M      | 384                 | 404   | 3             | 1     |
| 33 | Control   | 20  | F      | 453                 | 469   | 3             | 0     |
| 36 | Control   | 35  | M      | 445                 | 442   | 2             | 3     |
| 42 | Control   | 21  | F      | 508                 | 529   | 4             | 1     |
| 43 | Control   | 20  | M      | 432                 | 433   | 1             | 0     |
| 49 | Control   | 22  | F      | 431                 | 492   | 1             | 9     |
| 52 | Control   | 30  | F      | 397                 | 402   | 0             | 0     |
| 55 | Control   | 24  | M      | 443                 | 465   | 1             | 1     |
| 56 | Control   | 19  | F      | 555                 | 578   | 9             | 3     |
| 57 | Control   | 38  | M      | 477                 | 504   | 21            | 19    |
| 58 | Control   | 21  | F      | 385                 | 395   | 0             | 0     |
| 59 | Control   | 22  | F      | 416                 | 430   | 0             | 0     |
| 60 | Control   | 20  | F      | 535                 | 580   | 3             | 1     |
| 61 | Control   | 22  | F      | 517                 | 581   | 2             | 7     |
| 64 | Control   | 22  | M      | 557                 | 542   | 7             | 19    |
| 66 | Control   | 18  | F      | 464                 | 486   | 1             | 0     |
| 70 | Control   | 23  | F      | 434                 | 457   | 2             | 3     |
| 71 | Control   | 20  | F      | 543                 | 571   | 10            | 4     |
| 72 | Control   | 22  | M      | 416                 | 432   | 4             | 1     |
| 74 | Control   | 19  | F      | 443                 | 459   | 3             | 5     |
| 75 | Control   | 21  | F      | 502                 | 560   | 3             | 5     |
| 77 | Control   | 21  | F      | 449                 | 479   | 1             | 0     |
| 78 | Control   | 22  | M      | 520                 | 557   | 8             | 8     |
| 80 | Control   | 21  | M      | 418                 | 438   | 1             | 0     |
| 83 | Control   | 19  | F      | 416                 | 492   | 0             | 3     |
| 85 | Control   | 23  | F      | 458                 | 475   | 19            | 13    |
| 87 | Control   | 25  | F      | 432                 | 517   | 0             | 3     |
| 88 | Control   | 19  | M      | 462                 | 515   | 4             | 7     |
| 96 | Control   | 18  | M      | 437                 | 526   | 3             | 11    |
| 97 | Control   | 20  | F      | 422                 | 466   | 1             | 0     |
| 98 | Control   | 41  | F      | 385                 | 409   | 1             | 4     |
| 99 | Control   | 23  | F      | 469                 | 498   | 3             | 3     |
| 8  | Faking    | 22  | F      | 401                 | 408   | 1             | 0     |
| 10 | Faking    | 18  | F      | 435                 | 474   | 10            | 8     |
| 11 | Faking    | 22  | M      | 479                 | 585   | 20            | 16    |
| 12 | Faking    | 23  | F      | 446                 | 459   | 9             | 13    |
| 17 | Faking    | 23  | M      | 422                 | 439   | 0             | 0     |
| 18 | Faking    | 19  | F      | 431                 | 438   | 1             | 1     |
| 19 | Faking    | 21  | F      | 453                 | 469   | 3             | 5     |

|    |        |    |   |     |     |    |    |
|----|--------|----|---|-----|-----|----|----|
| 23 | Faking | 28 | M | 492 | 544 | 4  | 8  |
| 24 | Faking | 22 | M | 476 | 530 | 2  | 9  |
| 26 | Faking | 24 | F | 467 | 489 | 1  | 0  |
| 27 | Faking | 20 | M | 428 | 433 | 0  | 0  |
| 28 | Faking | 19 | M | 416 | 513 | 1  | 7  |
| 29 | Faking | 35 | F | 452 | 439 | 1  | 0  |
| 31 | Faking | 19 | M | 434 | 446 | 3  | 1  |
| 34 | Faking | 24 | F | 432 | 464 | 0  | 0  |
| 35 | Faking | -  | - | 509 | 545 | 14 | 17 |
| 37 | Faking | 29 | F | 452 | 496 | 1  | 1  |
| 38 | Faking | 22 | F | 313 | 305 | 1  | 0  |
| 39 | Faking | 21 | M | 476 | 509 | 2  | 4  |
| 40 | Faking | 20 | M | 456 | 479 | 58 | 31 |
| 41 | Faking | 18 | M | 417 | 455 | 9  | 7  |
| 44 | Faking | 20 | M | 386 | 403 | 0  | 0  |
| 46 | Faking | 21 | F | 547 | 550 | 7  | 1  |
| 47 | Faking | 20 | F | 359 | 366 | 56 | 54 |
| 48 | Faking | 39 | F | 581 | 611 | 25 | 12 |
| 50 | Faking | 22 | F | 396 | 427 | 0  | 0  |
| 51 | Faking | 19 | M | 376 | 426 | 0  | 4  |
| 53 | Faking | 23 | M | 461 | 470 | 1  | 1  |
| 54 | Faking | 20 | F | 409 | 433 | 5  | 5  |
| 62 | Faking | 19 | F | 481 | 511 | 1  | 0  |
| 63 | Faking | 23 | F | 483 | 495 | 2  | 0  |
| 65 | Faking | 23 | M | 486 | 552 | 7  | 15 |
| 67 | Faking | 23 | F | 446 | 507 | 0  | 8  |
| 68 | Faking | 22 | F | 471 | 515 | 1  | 4  |
| 69 | Faking | 21 | M | 564 | 546 | 8  | 13 |
| 73 | Faking | 30 | F | 366 | 375 | 6  | 3  |
| 76 | Faking | 19 | M | 451 | 457 | 4  | 7  |
| 79 | Faking | 18 | M | 617 | 619 | 46 | 15 |
| 81 | Faking | 22 | F | 422 | 428 | 10 | 9  |
| 82 | Faking | -  | - | 450 | 451 | 1  | 0  |
| 84 | Faking | 24 | - | 475 | 567 | 0  | 8  |
| 86 | Faking | 19 | M | 413 | 434 | 1  | 1  |
| 90 | Faking | 22 | F | 492 | 549 | 19 | 15 |
| 92 | Faking | 21 | F | 425 | 430 | 2  | 1  |
| 93 | Faking | -  | - | 488 | 499 | 8  | 12 |
| 94 | Faking | 20 | M | 431 | 477 | 2  | 4  |

Table A.4. Partners in Crime, Experiment 1 Data

| P  | Age | Gender | Motivation | Stress | Innocence | Immersion | Countermeasure             | Normalised Mean SCR |           |        | Normalised Mean HR |           |        |
|----|-----|--------|------------|--------|-----------|-----------|----------------------------|---------------------|-----------|--------|--------------------|-----------|--------|
|    |     |        |            |        |           |           |                            | Unknown             | Exclusive | Shared | Unknown            | Exclusive | Shared |
| 1  | 22  | M      | 4          | 2      | 4         | 5         | None                       | 0.815               | -0.266    | 1.901  | -0.574             | 0.100     | -0.479 |
| 2  | 22  | F      | 5          | 2      | 3         | 6         | None                       | 1.153               | 0.578     | 0.204  | -1.285             | 0.212     | -1.240 |
| 3  | 46  | F      | 6          | 1      | 6         | 5         | None                       | -0.306              | -0.306    | -0.306 | -0.049             | -0.703    | -0.439 |
| 4  | 47  | F      | 5          | 3      | 3         | 5         | Stay Calm                  |                     |           |        | -0.535             | 0.975     | 0.096  |
| 5  | 20  | F      | 4          | 4      | 4         | 5         | None                       | 0.760               | -0.571    | 0.227  | 0.565              | 0.194     | -0.160 |
| 6  | 18  | F      | 5          | 3      | 4         | 3         | Stay Calm                  | 0.181               | 0.090     | -0.064 | -0.920             | -0.489    | 0.034  |
| 7  | 22  | F      | 5          | 4      | 4         | 5         | None                       | 1.326               | 0.298     | 0.763  | -1.550             | -0.124    | -0.259 |
| 8  | 18  | F      | 5          | 5      | 3         | 4         | None                       | 0.771               | -0.274    | 0.435  | -0.810             | 0.209     | 0.050  |
| 9  | 22  | F      | 6          | 4      | 5         | 5         | Attended to controls       | -0.359              | -0.359    | 0.443  | -0.002             | -0.316    | 0.163  |
| 10 | 21  | F      | 5          | 2      | 2         | 3         | Suppressing' Memory        |                     |           |        | -0.767             | -0.839    | -0.797 |
| 11 | 21  | F      | 6          | 3      | 3         | 4         | Slow Heart Rate            | 0.939               | -0.114    | 0.305  | -0.307             | -0.377    | -0.682 |
| 12 | 24  | M      | 5          | 5      | 6         | 5         | Stay Calm                  | 0.416               | 0.086     | -0.348 | 0.002              | -0.998    | 0.149  |
| 13 | 23  | M      | 5          | 4      | 3         | 4         | None                       | -0.321              | -0.006    | 1.352  | -0.507             | 0.171     | 0.393  |
| 14 | 20  | F      | 6          | 5      | 2         | 5         | None                       | 0.271               | 0.493     | -0.229 | -0.419             | -0.035    | -0.077 |
| 16 | 19  | M      | 6          | 4      | 3         | 4         | None                       | 0.133               | 1.355     | -0.396 | 0.579              | -0.446    | -0.314 |
| 17 | -   | F      | 5          | 3      | 3         | 1         | None                       |                     |           |        | 0.326              | -1.134    | 0.334  |
| 18 | 23  | F      | 5          | 5      | 3         | 5         | Attended to controls       | 0.180               | 0.346     | -0.183 | -0.463             | -0.574    | -1.349 |
| 19 | 22  | F      | 5          | 4      | 2         | 4         | None                       | -0.224              | 0.409     | -0.063 | 0.488              | -1.261    | -0.997 |
| 20 | 32  | M      | 5          | 3      | 4         | 5         | None                       | 0.218               | -0.284    | 0.607  | -0.664             | -0.383    | -0.820 |
| 21 | 23  | F      | 6          | 6      | 4         | 6         | None                       | 1.156               | -0.524    | 0.252  | 0.461              | -0.156    | -0.919 |
| 22 | 19  | F      | 6          | 6      | 2         | 4         | None                       | -0.040              | 1.769     | 1.253  | -0.549             | -0.345    | -1.015 |
| 23 | 23  | F      | 5          | 4      | 4         | 4         | Attended to controls       | 0.324               | -0.338    | -0.109 | 0.110              | -0.418    | 0.155  |
| 24 | 18  | M      | 5          | 4      | 5         | 6         | None                       | -0.214              | 0.135     | 0.073  | 0.329              | 0.118     | 0.098  |
| 25 | 21  | F      | 5          | 2      | 5         | 3         | None                       | -0.366              | -0.221    | 0.060  | -1.216             | -0.561    | 0.282  |
| 26 | 21  | F      | 5          | 5      | 2         | 5         | None                       | 1.083               | 0.179     | 0.426  | -0.389             | -0.505    | -0.171 |
| 27 | 20  | F      | 5          | 2      | 5         | 4         | None                       | -0.308              | 0.908     | -0.308 | -0.097             | -0.206    | -0.795 |
| 28 | 31  | F      | 5          | 3      | 5         | 2         | Stay Calm                  | 0.898               | 0.664     | -0.299 | -0.633             | 0.474     | -0.267 |
| 29 | 18  | F      | 4          | 6      | 3         | 4         | Slow Heart Rate            | 0.056               | 0.206     | -0.269 | -0.927             | -0.842    | -0.221 |
| 30 | 20  | F      | 5          | 4      | 4         | 5         | None                       | 0.436               | 1.112     | 0.238  | -0.734             | -0.276    | 0.527  |
| 32 | 22  | F      | 5          | 2      | 4         | 4         | Think about something else | 1.196               | 1.079     | -0.409 | -0.247             | 0.226     | -0.348 |
| 33 | 22  | M      | 6          | 3      | 5         | 6         | Slow breathing             | 0.082               | 0.555     | -0.095 | 0.207              | -0.913    | 0.439  |
| 34 | 20  | M      | 5          | 4      | 2         | 5         | None                       | -0.080              | 1.386     | -0.142 | 0.306              | 0.377     | 0.025  |

Table A.5. Partners in Crime, Experiment 2 Data

| P   | Group | Order | Age | Gender | Motivation | Stress | Innocence | Immersion | Countermeasure             | Normalised Mean SCR |           |        | Normalised Mean HR |           |        |
|-----|-------|-------|-----|--------|------------|--------|-----------|-----------|----------------------------|---------------------|-----------|--------|--------------------|-----------|--------|
|     |       |       |     |        |            |        |           |           |                            | Unknown             | Exclusive | Shared | Unknown            | Exclusive | Shared |
| 1A  | -     | T     | 20  | F      | 5          | 2      | 4         | 5         | Attended to controls       | 0.448               | 0.611     | 2.011  | 0.902              | -0.380    | -0.011 |
| 1B  | -     | T     | 21  | M      | 5          | 4      | 4         | 4         | Covert Movement            | 1.217               | -0.417    | 0.608  | 0.896              | 0.253     | -0.353 |
| 2A  | -     | T     | 21  | F      | 6          | 4      | 4         | 6         | Attended to controls       |                     |           |        | 0.281              | -0.699    | 0.693  |
| 2B  | -     | T     | 21  | M      | 6          | 4      | 4         | 5         | None                       | 0.214               | -0.196    | 0.542  | 0.776              | -0.220    | 0.405  |
| 3A  | -     | T     | 20  | M      | 5          | 5      | 2         | 5         | Slow Breathing             | -0.344              | -0.134    | 2.038  | -0.140             | -0.200    | 0.853  |
| 3B  | -     | T     | 20  | M      | 5          | 3      | 2         | 4         | Attended to controls       | -0.570              | 0.154     | 0.094  | 0.418              | 0.264     | 0.011  |
| 4A  | -     | T     | 18  | F      | 5          | 2      | 5         | 4         | Think about something else | -0.386              | 1.142     | 0.082  | -0.016             | -0.627    | -0.691 |
| 4B  | -     | T     | 20  | F      | 4          | 2      | 5         | 5         | None                       |                     |           |        | 0.391              | -1.172    | -0.381 |
| 5A  | -     | T     | 20  | F      | 4          | 5      | 4         | 5         | None                       | -0.427              | 0.483     | 0.154  | -0.033             | -0.120    | -0.016 |
| 5B  | -     | T     | 20  | F      | 5          | 5      | 2         | 4         | Attended to controls       | -0.522              | 1.249     | 0.753  | 0.184              | -0.380    | 1.135  |
| 6A  | -     | T     | 28  | M      | 6          | 1      | 5         | 5         | Stay Calm                  | -0.085              | 1.300     | 0.737  | -0.267             | 0.430     | -0.587 |
| 6B  | -     | T     | 24  | M      | 5          | 4      | 6         | 5         | Stay Calm                  | -0.485              | 0.693     | 1.044  | -0.482             | -0.609    | 0.463  |
| 7A  | -     | T     | 18  | F      | 4          | 3      | 2         | 2         | Stay Calm                  | -0.228              | 1.475     | 0.588  | -0.330             | -1.538    | -1.099 |
| 7B  | -     | T     | 18  | M      | 5          | 2      | 4         | 4         | Think about something else | -0.487              | -0.358    | 0.345  | 0.851              | -0.821    | -1.285 |
| 8A  | -     | T     | 19  | F      | 4          | 4      | 3         | 5         | None                       | -0.053              | 0.212     | 1.350  | 0.394              | 0.092     | -0.438 |
| 8B  | -     | T     | 18  | F      | 6          | 4      | 2         | 3         | Stay Calm                  | -0.167              | 0.204     | 0.741  |                    | 0.477     | -0.976 |
| 9A  | -     | T     | 18  | M      | 6          | 4      | 2         | 5         | Stay Calm                  | -0.441              | 1.239     | 0.890  | 0.421              | -0.105    | -1.164 |
| 9B  | -     | T     | 19  | M      | 5          | 5      | 2         | 4         | Slow Breathing             | -0.140              | 0.515     | 1.391  |                    |           |        |
| 10A | -     | T     | 21  | F      | 5          | 3      | 4         | 4         | None                       | 1.478               | -0.062    | 1.655  | 0.024              | -0.063    | -0.646 |
| 10B | -     | T     | 21  | M      | 3          | 4      | 2         | 5         | None                       | 0.520               | 0.573     | 0.382  | 0.393              | -0.240    | -0.479 |
| 11A | -     | T     | 21  | F      | 5          | 4      | 3         | 4         | None                       | -0.368              | -0.252    | -0.231 | 0.543              | 0.145     | -1.029 |
| 11B | -     | T     | 23  | F      | 5          | 5      | 5         | 3         | None                       | -0.123              | -0.119    | 1.438  | -0.748             | 0.274     | -0.213 |
| 12a | 2     | S     | 27  | F      | 5          | 3      | 2         | 5         | None                       | 0.341               | -0.178    | 1.650  | 1.532              | -0.191    | -0.618 |
| 12b | 1     | S     | 28  | M      | 3          | 5      | 1         | 5         | Think about something else | -0.104              | 0.627     | -0.160 | -0.937             | -0.184    | -0.517 |
| 13a | 1     | S     | 21  | F      | 5          | 2      | 5         | 5         | None                       | -0.173              | 1.883     | 0.641  | 0.689              | -0.523    | -0.344 |
| 13b | 2     | S     | 23  | F      | 4          | 4      | 4         | 5         | None                       | 0.034               | 0.388     | 1.394  | 0.439              | 0.395     | -0.807 |
| 14a | 2     | S     | -   | -      | 5          | 2      | 1         | 6         | None                       | -0.109              | -0.160    | 0.020  | -0.711             | 0.120     | 0.248  |
| 14b | 1     | S     | -   | -      | 6          | 5      | 4         | 6         | Slow Breathing             | -0.267              | -0.267    | 0.764  | -0.415             | -0.450    | -1.481 |
| 15a | 1     | S     | 20  | M      | 4          | 2      | 4         | 5         | None                       | -0.185              | -0.288    | -0.057 | 0.089              | -0.510    | 0.188  |
| 15b | 2     | S     | 21  | F      | 4          | 3      | 5         | 4         | None                       | -0.311              | 0.785     | 1.794  | 0.543              | -0.073    | -0.825 |
| 16a | 1     | S     | 22  | F      | 5          | 4      | 3         | 6         | None                       | -0.346              | 2.183     | -0.264 | -0.979             | 0.375     | 0.145  |
| 16b | 2     | S     | 22  | F      | 5          | 3      | 4         | 4         | None                       | -0.314              | 1.962     | 0.169  | -0.660             | 0.526     | -0.803 |
| 17a | 2     | S     | 24  | M      | 4          | 2      | 4         | 5         | Think about something else | 1.167               | -0.203    | -0.176 | -0.376             | 0.423     | -0.158 |
| 17b | 1     | S     | 21  | F      | 6          | 2      | 4         | 6         | Heart Rate                 | 0.065               | 0.402     | 0.439  | -0.376             | -0.942    | -0.400 |
| 18a | 2     | S     | 19  | M      | 6          | 4      | 4         | 4         | Covert Movement            | 1.394               | 0.003     | 0.421  | -0.337             | -0.028    | -1.458 |
| 18b | 1     | S     | 18  | M      | 5          | 4      | 3         | 1         | Attended to controls       | 1.218               | -0.151    | 0.524  | -0.730             | 0.247     | -0.278 |
| 19a | 1     | S     | 18  | F      | 6          | 4      | 4         | 6         | None                       | -0.257              | 1.456     | -0.230 | -0.549             | -1.657    | 0.066  |
| 19b | 2     | S     | 19  | F      | 5          | 4      | 3         | 6         | None                       | -0.250              | 0.313     | 0.700  | -0.471             | -0.064    | -0.875 |
| 20A | -     | T     | 19  | M      | 4          | 2      | 3         | 6         | None                       | 0.523               | -0.569    | 0.602  | -0.301             | -1.377    | -0.311 |
| 20B | -     | T     | 21  | M      | 5          | 2      | 6         | 4         | None                       | 0.560               | 0.626     | 1.052  | -0.298             | 0.037     | 0.289  |
| 21a | 1     | S     | 23  | M      | 5          | 2      | 4         | 3         | None                       | 0.470               | 1.050     | 0.922  | 0.603              | -0.316    | -0.159 |
| 21b | 2     | S     | 22  | M      | 5          | 1      | 6         | 3         | None                       | -0.089              | -0.366    | -0.360 | 0.184              | -1.811    | 0.196  |
| 22a | 2     | S     | 22  | M      | 3          | 3      | 2         | 3         | None                       | 0.168               | 0.818     | 0.247  | 0.241              | 0.531     | -0.443 |
| 22b | 1     | S     | 21  | M      | 6          | 3      | 5         | 3         | None                       | -0.219              | -0.244    | -0.186 | -0.288             | -0.868    | -0.392 |
| 23a | 1     | S     | 20  | M      | 6          | 5      | 3         | 6         | Slow Breathing             | -0.693              | 0.530     | 0.151  | 0.601              | -0.557    | -0.097 |
| 23b | 2     | S     | 19  | F      | 6          | 5      | 3         | 5         | None                       | -0.424              | 0.345     | 0.687  | 0.118              | 0.329     | 0.158  |
| 24A | -     | T     | 26  | M      | 6          | 1      | 4         | 6         | Think about something else | 0.201               | 0.092     | 1.638  | 0.223              | -0.914    | -0.361 |
| 24B | -     | T     | 25  | M      | 5          | 3      | 5         | 5         | None                       | -0.504              | 0.871     | 1.265  | -0.236             | -0.183    | -0.110 |
| 25A | -     | T     | 18  | M      | 6          | 4      | 2         | 5         | None                       | -0.103              | 1.462     | 0.531  | 0.151              | -0.357    | -0.405 |
| 25B | -     | T     | 19  | M      | 6          | 4      | 3         | 4         | None                       | 1.256               | 0.921     | -0.199 | -0.545             | -0.135    | -0.017 |
| 26a | 2     | S     | 23  | F      | 5          | 4      | 4         | 4         | None                       | 0.145               | 0.004     | -0.171 | -0.310             | -0.153    | -0.810 |
| 26b | 1     | S     | 23  | F      | 5          | 4      | 4         | 4         | None                       | -0.167              | -0.167    | -0.167 |                    |           |        |

|     |   |   |    |   |   |   |   |   |                            |        |        |        |        |        |        |
|-----|---|---|----|---|---|---|---|---|----------------------------|--------|--------|--------|--------|--------|--------|
| 27a | 1 | S | 19 | F | 5 | 2 | 4 | 5 | Attended to controls       | -0.515 | 1.162  | 0.809  |        |        |        |
| 27b | 2 | S | 21 | F | 5 | 5 | 3 | 5 | None                       | -0.263 | 1.624  | -0.050 |        |        |        |
| 29A | - | T | 21 | F | 5 | 4 | 2 | 4 | None                       | -0.183 | -0.054 | 1.734  |        |        |        |
| 29B | - | T | 20 | F | 5 | 4 | 2 | 4 | Think about something else | -0.111 | 0.877  | 0.824  | -0.346 | -0.361 | -0.137 |
| 30a | 1 | S | 19 | M | 6 | 2 | 5 | 2 | None                       | -0.296 | 0.445  | 0.851  | 0.574  | 0.421  | -0.654 |
| 30b | 2 | S | 19 | M | 6 | 4 | 4 | 4 | None                       | -0.457 | 0.870  | 0.277  | 0.194  | -0.489 | -0.974 |
| 31a | 2 | S | 21 | M | 6 | 2 | 5 | 5 | Think about something else | 0.413  | 1.045  | 0.586  | 0.277  | -0.435 | -0.309 |
| 31b | 1 | S | 19 | F | 5 | 1 | 4 | 3 | None                       | 0.906  | 0.184  | -0.378 | 0.196  | -0.053 | -0.737 |
| 32A | - | T | 22 | M | 3 | 6 | 4 | 3 | None                       | 0.301  | 0.233  | 0.953  | 0.160  | 0.877  | -1.061 |
| 32B | - | T | 22 | M | 5 | 3 | 3 | 5 | None                       | -0.279 | 0.542  | 2.202  | -1.527 | 0.108  | 0.898  |
| 33A | 1 | S | 32 | M | 6 | 4 | 6 | 6 | None                       | 0.128  | 0.948  | -0.197 | -0.013 | 0.164  | -0.459 |
| 33B | 2 | S | 24 | F | 6 | 5 | 1 | 4 | Think about something else | -0.473 | 0.976  | -0.342 | 0.840  | -0.017 | -0.185 |

Table A.6. *Partners in Crime, Experiment 3 Data*

| P   | Group | Order | Age | Gender | Motivation | Stress | Innocence | Immersion | Countermeasure             | Normalised Mean SCR |           |        | Normalised Mean HR |           |        |
|-----|-------|-------|-----|--------|------------|--------|-----------|-----------|----------------------------|---------------------|-----------|--------|--------------------|-----------|--------|
|     |       |       |     |        |            |        |           |           |                            | Unknown             | Exclusive | Shared | Unknown            | Exclusive | Shared |
| 1A  | -     | T     | 19  | M      | 5          | 1      | 4         | 5         | None                       | -0.400              | 0.899     | 0.429  | 0.256              | 0.171     | -0.021 |
| 1B  | -     | T     | 18  | M      | 6          | 2      | 5         | 4         | None                       | -0.447              | 0.433     | -0.245 | 0.238              | -0.837    | -0.058 |
| 2a  | 1     | S     | 18  | F      | 6          | 2      | 4         | 5         | None                       | -0.398              | 0.627     | 0.252  | 0.532              | 0.405     | 0.092  |
| 2b  | 2     | S     | 19  | F      | 6          | 3      | 5         | 4         | None                       | -0.066              | 0.950     | 0.232  | 0.327              | -0.145    | -0.090 |
| 3A  | -     | T     | 18  | F      | 5          | 3      | 4         | 4         | None                       | -0.904              | -0.429    | 0.487  | 0.162              | -1.188    | -0.341 |
| 3B  | -     | T     | 18  | F      | 6          | 2      | 2         | 5         | None                       | -0.291              | 1.154     | 1.816  | -0.072             | -0.441    | -0.229 |
| 4A  | -     | T     | 18  | F      | 4          | 1      | 5         | 3         | None                       | -0.094              | -0.265    | 0.985  | 0.163              | 0.410     | -0.762 |
| 4B  | -     | T     | 18  | F      | 1          | 1      | 2         | 2         | None                       | 1.179               | -0.175    | -0.247 | 1.151              | -0.910    | -0.616 |
| 5a  | 2     | S     | 18  | F      | 5          | 2      | 3         | 6         | Think about something else | -0.087              | 0.493     | -0.400 | 0.031              | -0.693    | -1.588 |
| 5b  | 1     | S     | 18  | F      | 4          | 2      | 3         | 4         | None                       | 0.625               | -0.613    | 0.804  | 0.822              | 0.185     | -0.704 |
| 6a  | 2     | S     | 19  | F      | 4          | 5      | 3         | 6         | Slow Breathing             | 0.084               | 1.002     | 0.908  | -0.454             | -0.179    | -0.970 |
| 6b  | 1     | S     | 19  | F      | 6          | 2      | 4         | 4         | Think about something else | -0.215              | 1.199     | 0.257  | 0.698              | -0.874    | 0.510  |
| 7a  | 1     | S     | 18  | F      | 5          | 2      | 4         | 5         | Stay Calm                  | -0.267              | 0.914     | -0.186 | 0.693              | -0.308    | 0.051  |
| 7b  | 2     | S     | 18  | F      | 6          | 4      | 2         | 4         | Slow Breathing             | -0.398              | -0.312    | 0.384  | 0.070              | -0.022    | -0.227 |
| 8a  | 2     | S     | 18  | F      | 4          | 4      | 3         | 5         | None                       | -0.678              | 0.862     | 0.774  | 0.595              | -1.287    | -0.480 |
| 8b  | 1     | S     | 18  | M      | 4          | 3      | 1         | 5         | None                       | -0.171              | -0.125    | -0.171 | 0.367              | 0.202     | 0.138  |
| 9a  | 1     | S     | 18  | F      | 5          | 4      | 3         | 4         | Slow Breathing             |                     |           |        | 0.053              | 0.470     | -0.587 |
| 9b  | 2     | S     | 18  | F      | 5          | 3      | 3         | 4         | None                       | -0.836              | -0.015    | 0.474  | 0.545              | 0.100     | 0.476  |
| 10A | -     | T     | 18  | F      | 6          | 2      | 4         | 4         | Slow Breathing             | -0.314              | -0.314    | 1.534  | -0.413             | -0.322    | 0.152  |
| 10B | -     | T     | 18  | F      | 5          | 5      | 3         | 4         | None                       | 0.147               | 0.956     | 0.524  |                    |           |        |
| 11A | -     | T     | 19  | F      | 5          | 3      | 3         | 5         | None                       | -0.321              | 0.266     | 0.665  | 0.497              | 0.072     | -0.421 |
| 11B | -     | T     | 18  | F      | 5          | 6      | 3         | 5         | None                       | -0.288              | -0.183    | 1.745  | 0.603              | -0.699    | -1.352 |
| 12A | -     | T     | 19  | F      | 5          | 2      | 4         | 5         | None                       |                     |           |        | 0.088              | 0.738     | 0.109  |
| 12B | -     | T     | 19  | F      | 6          | 3      | 4         | 4         | None                       | -0.473              | -0.160    | 0.427  | 0.574              | -0.103    | -0.074 |
| 13A | -     | T     | 18  | F      | 5          | 2      | 3         | 3         | None                       | -0.194              | -0.143    | 1.830  | 0.460              | 0.620     | -1.251 |
| 13B | -     | T     | 18  | F      | 5          | 3      | 4         | 4         | Slow Breathing             | 0.115               | 0.046     | -0.519 | 0.380              | -0.569    | -0.153 |
| 14A | -     | T     | 18  | F      | 5          | 3      | 2         | 3         | None                       | -0.558              | -0.484    | 0.560  | -0.305             | -0.189    | -0.157 |
| 14B | -     | T     | 18  | F      | 5          | 4      | 4         | 5         | None                       | -0.382              | 0.369     | 1.797  | -0.677             | 0.268     | 0.367  |
| 15a | 1     | S     | 18  | F      | 6          | 5      | 2         | 6         | None                       | -0.561              | 0.492     | -0.310 | -0.816             | -0.235    | -1.030 |
| 15b | 2     | S     | 19  | F      | 5          | 3      | 4         | 4         | None                       | 0.468               | 0.770     | -0.218 | -0.212             | -0.061    | -1.113 |
| 16a | 2     | S     | 18  | F      | 6          | 4      | 3         | 5         | Heart Rate                 | -0.688              | 2.135     | 1.593  | 0.936              | -0.504    | -0.457 |
| 16b | 1     | S     | 18  | M      | 5          | 2      | 4         | 4         | None                       | 0.025               | 1.196     | -0.180 | -0.266             | 0.897     | -0.336 |
| 17a | 2     | S     | 18  | F      | 5          | 1      | 3         | 5         | None                       | -0.433              | 0.066     | 0.121  | -0.893             | -0.557    | -0.021 |
| 17b | 1     | S     | 18  | F      | 3          | 3      | 2         | 5         | None                       | 0.409               | 1.029     | 0.468  | 0.073              | 0.422     | 1.258  |
| 18a | 1     | S     | 19  | F      | 5          | 4      | 3         | 4         | Slow Breathing             | -0.701              | 1.478     | 0.996  | -0.721             | -0.879    | -0.293 |
| 18b | 2     | S     | 18  | F      | 5          | 4      | 2         | 5         | Slow Breathing             | -0.127              | 1.006     | 1.853  | 0.784              | -0.746    | -0.203 |
| 19A | -     | T     | 19  | F      | 5          | 2      | 2         | 3         | None                       | -0.655              | 0.500     | -0.219 | 0.065              | -0.565    | 0.422  |
| 19B | -     | T     | 18  | F      | 4          | 3      | 4         | 3         | Stay Calm                  |                     |           |        | 0.472              | 0.444     | 0.272  |
| 21a | 2     | S     | 18  | F      | 5          | 1      | 3         | 4         | None                       | -0.354              | 0.408     | 0.492  | -0.318             | -0.070    | -0.001 |
| 21b | 1     | S     | 18  | F      | 6          | 3      | 3         | 3         | None                       |                     |           |        | -0.224             | -1.252    | -0.839 |
| 22A | -     | T     | 18  | F      | 5          | 3      | 2         | 5         | Slow Breathing             | -0.270              | 0.980     | 1.343  | 0.397              | -1.137    | 0.602  |
| 22B | -     | T     | 18  | F      | 5          | 4      | 4         | 5         | Heart Rate                 | -0.494              | 0.523     | -0.075 | 0.311              | -0.041    | 0.180  |
| 23a | 1     | S     | 19  | F      | 5          | 5      | 4         | 5         | Heart Rate                 | -0.546              | -0.099    | 0.355  | 0.505              | -1.164    | -0.122 |
| 23b | 2     | S     | 18  | F      | 5          | 2      | 4         | 6         | Slow Breathing             | -0.369              | -0.187    | -0.369 | -0.061             | -0.378    | -0.128 |
| 24a | 2     | S     | 18  | F      | 5          | 4      | 5         | 5         | None                       | -0.315              | -0.023    | -0.315 | -0.216             | -0.324    | -0.527 |
| 24b | 1     | S     | 18  | F      | 5          | 3      | 4         | 4         | None                       |                     |           |        | 0.315              | -0.013    | -0.755 |
| 25a | 1     | S     | 18  | F      | 4          | 2      | 4         | 5         | None                       |                     |           |        | -0.273             | 0.523     | -0.111 |
| 25b | 2     | S     | 18  | F      | 5          | 2      | 4         | 4         | None                       | -0.489              | -0.374    | 0.238  | -0.491             | -0.335    | -0.577 |
| 26a | 2     | S     | 18  | F      | 6          | 2      | 5         | 4         | None                       | -0.481              | 0.315     | 1.641  | -1.057             | -0.441    | 0.476  |

|     |   |   |    |   |   |   |   |   |                            |        |        |        |        |        |        |
|-----|---|---|----|---|---|---|---|---|----------------------------|--------|--------|--------|--------|--------|--------|
| 26b | 1 | S | 20 | F | 5 | 4 | 2 | 4 | None                       | -0.310 | 0.073  | -0.310 | 0.099  | 0.817  | 0.242  |
| 27a | 1 | S | 19 | F | 6 | 4 | 3 | 4 | None                       | -0.412 | -0.340 | -0.198 | 0.377  | -0.632 | -0.415 |
| 27b | 2 | S | 20 | F | 4 | 1 | 4 | 5 | Think about something else | -0.242 | -0.007 | -0.073 | -0.090 | -0.508 | 0.372  |
| 28A | - | T | 18 | M | 5 | 2 | 4 | 3 | None                       | -0.017 | 0.184  | 1.408  | -0.204 | -0.563 | -0.046 |
| 28B | - | T | 22 | M | 5 | 4 | 5 | 5 | None                       | -0.709 | 1.478  | 1.666  | -0.062 | -0.135 | -0.676 |
| 29A | - | T | 18 | F | 4 | 4 | 3 | 2 | None                       |        |        |        | 0.041  | 0.464  | 0.284  |
| 29B | - | T | 18 | F | 5 | 2 | 4 | 6 | None                       |        |        |        | -0.229 | -0.405 | -0.402 |
| 30A | - | T | 19 | F | 5 | 3 | 4 | 4 | Slow Breathing             | 0.386  | 0.741  | 1.519  | 0.101  | -0.546 | -1.239 |
| 30B | - | T | 18 | F | 5 | 4 | 5 | 4 | None                       |        |        |        | 1.051  | -0.878 | 0.478  |
| 31A | - | T | 18 | F | 5 | 3 | 4 | 4 | None                       | -0.248 | 0.370  | 2.003  | 0.428  | -0.888 | -1.035 |
| 31B | - | T | 20 | F | 5 | 6 | 4 | 4 | None                       |        |        |        | -1.167 | 0.386  | 0.304  |
| 33A | - | T | 18 | F | 5 | 5 | 2 | 5 | Think about something else | -0.481 | -0.011 | 0.534  | -0.954 | -0.854 | 0.191  |
| 33B | - | T | 18 | F | 4 | 2 | 5 | 4 | Heart Rate                 | 0.955  | -0.476 | 0.224  | -0.479 | -0.426 | -0.520 |
| 34A | - | T | 18 | F | 5 | 1 | 3 | 4 | None                       |        |        |        | 0.870  | -0.510 | -0.517 |
| 34B | - | T | 19 | F | 5 | 4 | 4 | 4 | None                       | -0.315 | -0.077 | 0.314  | -0.408 | -0.677 | -0.341 |
| 35A | - | T | 18 | F | 6 | 2 | 2 | 5 | Stay Calm                  | -0.610 | 0.044  | -0.251 | -0.091 | -0.602 | -0.552 |
| 35B | - | T | 18 | F | 4 | 3 | 3 | 4 | Heart Rate                 | -0.467 | 0.696  | 0.033  | -1.688 | 0.371  | -0.826 |
| 37A | - | T | 18 | F | 4 | 2 | 3 | 4 | None                       | -0.446 | 0.907  | 0.706  | -0.323 | -0.235 | -0.714 |
| 37B | - | T | 19 | F | 4 | 2 | 3 | 5 | None                       | 0.287  | 0.117  | 0.098  | -0.224 | 1.316  | -0.422 |
| 38A | - | T | 19 | F | 5 | 1 | 5 | 3 | None                       | -0.488 | 0.871  | 0.070  | -0.174 | -0.647 | -0.039 |
| 38B | - | T | 19 | F | 4 | 1 | 3 | 5 | None                       |        |        |        | 0.248  | -0.051 | 0.353  |
| 39A | - | T | 19 | F | 6 | 3 | 3 | 6 | Slow Breathing             | -0.400 | -0.560 | 1.254  | 0.490  | -0.172 | 0.239  |
| 39B | - | T | 19 | F | 5 | 2 | 3 | 5 | Slow Breathing             | -0.259 | -0.259 | -0.041 | 0.042  | -1.188 | 0.324  |
| 40A | - | T | 18 | F | 6 | 4 | 3 | 5 | None                       | -0.222 | 0.420  | 0.238  | 0.253  | -1.597 | -1.414 |
| 40B | - | T | 19 | F | 6 | 4 | 4 | 4 | Think about something else | -0.167 | -0.167 | -0.167 | 0.926  | -0.199 | -0.931 |
| 43a | 1 | S | 18 | F | 5 | 6 | 4 | 5 | Slow Breathing             | -0.441 | 1.104  | 0.674  | -0.210 | 0.047  | 0.863  |
| 43b | 2 | S | 19 | F | 5 | 3 | 3 | 4 | Heart Rate                 | -0.444 | 0.477  | 0.017  | 0.547  | -0.735 | 0.541  |
| 44a | 1 | S | 19 | F | 5 | 2 | 4 | 4 | Think about something else | -0.347 | -0.329 | -0.263 | 0.190  | -0.064 | -0.764 |
| 44b | 2 | S | 19 | F | 6 | 1 | 4 | 5 | None                       | -0.620 | 1.222  | -0.058 | 0.036  | 0.070  | -0.541 |
| 46a | 2 | S | 18 | F | 5 | 5 | 2 | 6 | None                       | -0.296 | -0.121 | -0.170 | -1.641 | 0.030  | -0.664 |
| 46b | 1 | S | 18 | F | 5 | 4 | 3 | 4 | None                       | -0.233 | -0.139 | -0.233 | 0.795  | -0.505 | 0.243  |
| 47A | - | T | 18 | M | 5 | 4 | 4 | 4 | None                       | 0.388  | 0.559  | 0.959  | -0.361 | -1.010 | -0.170 |
| 47B | - | T | 18 | F | 5 | 3 | 4 | 4 | None                       | -0.363 | 1.912  | 0.465  | 0.660  | -0.729 | -0.574 |
| 48a | 2 | S | 19 | F | 5 | 3 | 4 | 3 | None                       | 0.444  | 0.310  | -0.412 | 0.787  | 0.585  | -0.901 |
| 48b | 1 | S | 19 | F | 4 | 3 | 4 | 5 | None                       | -0.290 | 1.491  | 0.695  | -0.314 | -1.257 | -0.260 |



*Table A.7. Partners in Crime, Experiment 4 Data*

| P   | Age | Gender | Mean Reaction Time |       | Mean % Error |       |
|-----|-----|--------|--------------------|-------|--------------|-------|
|     |     |        | Control            | Crime | Control      | Crime |
| 1A  | 20  | F      | 451                | 489   | 1            | 3     |
| 1B  | 18  | F      | 448                | 472   | 1            | 5     |
| 2A  | 24  | M      | 409                | 420   | 0            | 0     |
| 2B  | 22  | M      | 411                | 425   | 0            | 0     |
| 3A  | 21  | M      | 392                | 376   | 1            | 0     |
| 3B  | 20  | F      | 405                | 418   | 0            | 0     |
| 4A  | 18  | M      | 411                | 443   | 2            | 4     |
| 4B  | 21  | M      | 466                | 502   | 6            | 13    |
| 5A  | 18  | F      | 437                | 456   | 2            | 5     |
| 5B  | 20  | M      | 435                | 444   | 1            | 4     |
| 6A  | 19  | F      | 410                | 450   | 1            | 4     |
| 6B  | 19  | M      | 381                | 427   | 1            | 4     |
| 7A  | 18  | F      | 418                | 493   | 1            | 0     |
| 7B  | 20  | M      | 402                | 442   | 1            | 0     |
| 8A  | 19  | F      | 436                | 502   | 0            | 8     |
| 8B  | 19  | F      | 459                | 467   | 1            | 3     |
| 9A  | 19  | F      | 389                | 408   | 3            | 3     |
| 9B  | 23  | F      | 412                | 430   | 5            | 1     |
| 10A | 20  | M      | 397                | 395   | 3            | 1     |
| 10B | 21  | F      | 436                | 428   | 10           | 13    |
| 11A | 21  | M      |                    |       |              |       |
| 11B | 19  | F      | 487                | 506   | 4            | 3     |
| 12A | 19  | F      |                    |       |              |       |
| 12B | 18  | F      |                    |       |              |       |
| 13A | 18  | F      | 419                | 462   | 1            | 1     |
| 13B | 18  | F      | 464                | 487   | 2            | 0     |
| 14A | 21  | F      | 420                | 429   | 6            | 3     |
| 14B | 19  | F      | 434                | 462   | 2            | 4     |
| 15A | 23  | F      | 458                | 530   | 1            | 5     |
| 15B | 26  | F      | 417                | 438   | 5            | 4     |

Table A.8. *Partners in Crime, Experiment 5 Data*

| P   | Order | Age | Gender | Mean Reaction Times |       |         |       | Mean % Errors |       |         |       |
|-----|-------|-----|--------|---------------------|-------|---------|-------|---------------|-------|---------|-------|
|     |       |     |        | Individual          |       | Paired  |       | Individual    |       | Paired  |       |
|     |       |     |        | Control             | Crime | Control | Crime | Control       | Crime | Control | Crime |
| 1A  | 1     | 22  | M      | 467                 | 573   | 475     | 562   | 0             | 1     | 0       | 0     |
| 1B  | 1     | 25  | M      | 455                 | 513   | 478     | 565   | 0             | 1     | 1       | 3     |
| 2A  | 1     | 20  | M      | 436                 | 519   | 466     | 495   | 0             | 1     | 0       | 1     |
| 2B  | 1     | 20  | M      | 415                 | 450   | 465     | 500   | 1             | 0     | 3       | 0     |
| 3A  | 1     | 24  | M      | 390                 | 410   | 461     | 497   | 0             | 1     | 0       | 1     |
| 3B  | 1     | 24  | M      | 416                 | 476   | 458     | 492   | 0             | 4     | 1       | 1     |
| 4A  | 1     | 20  | M      | 403                 | 446   | 451     | 544   | 0             | 1     | 1       | 0     |
| 4B  | 1     | 21  | M      | 407                 | 487   | 442     | 530   | 1             | 0     | 1       | 1     |
| 5A  | 1     | 21  | M      | 377                 | 437   | 410     | 462   | 0             | 0     | 6       | 8     |
| 5B  | 1     | 20  | M      | 444                 | 474   | 415     | 475   | 2             | 7     | 6       | 8     |
| 6A  | 1     | 21  | M      | 381                 | 403   | 471     | 506   | 0             | 0     | 2       | 0     |
| 6B  | 1     | 20  | M      | 402                 | 409   | 441     | 474   | 0             | 1     | 1       | 3     |
| 7A  | 1     | 20  | F      | 390                 | 406   | 437     | 433   | 1             | 1     | 0       | 0     |
| 7B  | 1     | 21  | F      | 399                 | 396   | 414     | 413   | 1             | 1     | 1       | 1     |
| 8A  | 1     | 21  | F      | 383                 | 419   | 473     | 512   | 1             | 0     | 1       | 0     |
| 8B  | 1     | 20  | F      | 403                 | 410   | 448     | 464   | 1             | 0     | 2       | 3     |
| 9A  | 1     | 23  | M      | 402                 | 421   | 416     | 492   | 0             | 1     | 0       | 0     |
| 9B  | 1     | 20  | M      | 393                 | 418   | 395     | 452   | 1             | 1     | 0       | 4     |
| 10A | 1     | 20  | M      | 386                 | 373   | 423     | 498   | 0             | 1     | 1       | 0     |
| 10B | 1     | 21  | M      | 435                 | 514   | 407     | 470   | 1             | 3     | 1       | 1     |
| 11A | 2     | 21  | M      | 410                 | 490   | 447     | 476   | 0             | 3     | 1       | 0     |
| 11B | 2     | 20  | M      | 397                 | 405   | 430     | 444   | 0             | 0     | 0       | 5     |
| 12A | 2     | 20  | M      | 401                 | 426   | 444     | 504   | 0             | 3     | 0       | 0     |
| 12B | 2     | 21  | M      | 411                 | 429   | 427     | 478   | 0             | 4     | 1       | 1     |
| 13A | 2     | 22  | M      | 409                 | 426   | 440     | 456   | 1             | 3     | 0       | 0     |
| 13B | 2     | 23  | M      | 381                 | 430   | 410     | 430   | 1             | 1     | 1       | 0     |
| 14A | 2     | 21  | M      | 371                 | 392   | 473     | 493   | 1             | 1     | 0       | 1     |
| 14B | 2     | 20  | M      | 390                 | 408   | 437     | 448   | 1             | 0     | 0       | 1     |
| 15A | 2     | 20  | M      | 375                 | 449   | 500     | 515   | 1             | 0     | 2       | 1     |
| 15B | 2     | 20  | M      | 372                 | 392   | 455     | 461   | 0             | 1     | 2       | 3     |
| 16A | 2     | 21  | M      | 373                 | 388   | 496     | 525   | 0             | 0     | 1       | 1     |
| 16B | 2     | 21  | M      | 376                 | 376   | 440     | 463   | 0             | 0     | 2       | 1     |
| 17A | 2     | 22  | M      | 366                 | 364   | 457     | 465   | 0             | 1     | 0       | 0     |
| 17B | 2     | 24  | M      | 397                 | 409   | 420     | 428   | 0             | 0     | 0       | 0     |
| 18A | 2     | 20  | M      | 384                 | 392   | 465     | 459   | 2             | 1     | 1       | 4     |
| 18B | 2     | 21  | M      | 394                 | 401   | 428     | 424   | 0             | 0     | 2       | 1     |
| 19A | 2     | 21  | M      | 408                 | 422   | 437     | 440   | 1             | 3     | 1       | 0     |
| 19B | 2     | 20  | M      | 408                 | 434   | 403     | 408   | 1             | 1     | 1       | 1     |
| 20A | 2     | 22  | M      | 416                 | 430   | 450     | 495   | 2             | 4     | 1       | 1     |
| 20B | 2     | 21  | M      | 407                 | 437   | 415     | 451   | 1             | 0     | 1       | 3     |

Table A.9. Partners in Crime, Experiment 6 Data

| P   | Partner | A 1st | Age | Gender | Motivatio | Stress | Innocence | Countermeasures          | Mean Reaction Times |           |        | Mean % Errors |           |        |
|-----|---------|-------|-----|--------|-----------|--------|-----------|--------------------------|---------------------|-----------|--------|---------------|-----------|--------|
|     |         |       |     |        |           |        |           |                          | None                | Exclusive | Shared | None          | Exclusive | Shared |
| 1A  | 1       | S     | 18  | F      | 5         | 2      | 2         | None                     | -20                 | 34        | 56     | 0             | 7         | 7      |
| 1B  | 2       | S     | 18  | F      | 6         | 1      | 2         | None                     | 4                   | -41       | 53     | -1            | 0         | 11     |
| 2A  | 2       | S     | 20  | F      | 5         | 2      | 3         | None                     | 19                  | 12        | 12     | 0             | 0         | -2     |
| 2B  | 1       | S     |     |        | 5         | 4      | 3         | None                     | -26                 | 12        | 19     | 0             | -1        | 6      |
| 3A  |         | T     |     |        | 2         | 6      | 1         | None                     | -3                  | 2         | 11     | -4            | -3        | 3      |
| 3B  |         | T     | 21  | F      | 5         | 4      | 1         | None                     | -27                 | -47       | 4      | 4             | 0         | -7     |
| 4A  | 1       | S     | 21  | F      | 5         | 4      | 3         | None                     | -28                 | 13        | 33     | 0             | 4         | 0      |
| 4B  | 2       | S     | 20  | M      | 5         | 3      | 4         | None                     | 4                   | -16       | 41     | 0             | 0         | 4      |
| 5A  | 1       | S     | 20  | M      | 5         | 1      | 2         | Made intentional errors  | -4                  | -12       | 8      | 0             | 0         | 1      |
| 5B  | 2       | S     | 21  | M      | 6         | 5      | 2         | None                     | -6                  | -4        | 30     | 0             | 2         | 7      |
| 6A  |         | T     |     |        | 5         | 4      | 3         | None                     | -10                 | 45        | 26     | -1            | 7         | 4      |
| 6B  |         | T     |     |        | 4         | 2      | 3         | None                     | 35                  | -17       | -13    | -1            | -1        | 12     |
| 7A  |         | T     | 21  | F      | 4         | 3      | 2         | None                     | 28                  | -19       | 33     | 0             | 4         | 2      |
| 7B  |         | T     | 20  | F      | 5         | 3      | 2         | None                     | 6                   | 13        | 30     | -4            | -2        | -3     |
| 8A  | 2       | S     | 19  | M      | 5         | 2      | 4         | Respond same time        | -11                 | 63        | 45     | 0             | 6         | 1      |
| 8B  | 1       | S     | 20  | M      | 6         | 4      | 4         | None                     | 11                  | 68        | 55     | 2             | 6         | -4     |
| 9A  | 1       | S     |     |        | 4         | 2      | 3         | None                     | -10                 | 10        | -16    | -1            | 4         | 7      |
| 9B  | 2       | S     |     |        |           |        |           | None                     | -7                  | 4         | 30     | -1            | 7         | 9      |
| 10A |         | T     | 18  | M      | 5         | 5      | 1         | None                     | -4                  | -8        | -11    | 0             | -2        | 0      |
| 10B |         | T     | 19  | M      | 5         | 2      | 2         | None                     | -28                 | -9        | 8      | -4            | 0         | 5      |
| 11A |         | T     | 20  | F      | 5         | 4      | 3         | None                     | -30                 | -14       | 42     | 0             | 2         | 7      |
| 11B |         | T     | 21  | M      | 6         | 4      | 3         | None                     | 8                   | -5        | 74     | 0             | 0         | 0      |
| 12A | 2       | S     | 21  | F      | 5         | 5      | 3         | None                     | -21                 | 46        | 19     | 0             | 4         | -1     |
| 12B | 1       | S     | 20  | F      | 5         | 3      | 3         | None                     | 4                   | 5         | 25     | 0             | 0         | 7      |
| 13A |         | T     | 22  | F      | 5         | 2      | 5         | None                     | -14                 | -45       | 7      | 0             | 3         | 0      |
| 13B |         | T     | 21  | F      | 5         | 4      | 4         | None                     | -39                 | 5         | -2     | 2             | 0         | 2      |
| 14A | 2       | S     | 20  | F      | 5         | 5      | 2         | Respond faster to crimes | -21                 | -26       | 46     | 0             | 4         | 7      |
| 14B | 1       | S     | 19  | F      | 5         | 4      | 2         | None                     | -15                 | -40       | 15     | 0             | 0         | 9      |
| 15A |         | T     | 19  | F      | 5         | 3      | 2         | None                     | 4                   | -8        | 4      | 0             | -2        | -2     |
| 15B |         | T     | 19  | F      | 6         | 6      | 2         | None                     | -5                  | -11       | -1     | -2            | -1        | 3      |
| 16A | 2       | S     | 20  |        | 5         | 4      | 1         | None                     | -23                 | 16        | 19     | -1            | -2        | 10     |
| 16B | 1       | S     | 19  | M      | 6         | 2      | 4         | None                     | -17                 | -6        | -10    | 0             | -2        | -3     |
| 17A | 2       | S     | 19  | F      | 4         | 4      | 2         | None                     | -3                  | 13        | 37     | -1            | 0         | 4      |
| 17B | 1       | S     | 20  | F      | 5         | 3      | 2         | None                     | -41                 | -8        | 11     | -1            | 3         | 15     |
| 18A |         | T     |     | M      | 5         | 3      | 1         | None                     | 4                   | -18       | 43     | 0             | 2         | 7      |
| 18B |         | T     |     | M      | 4         | 5      | 3         | None                     | -7                  | 0         | 35     | -1            | 0         | 3      |
| 19A |         | T     |     | F      | 5         | 2      | 4         | None                     | -11                 | -19       | 41     | 0             | 4         | 0      |
| 19B |         | T     |     | F      | 5         | 4      | 2         | Slowed all responses     | -30                 | -3        | 42     | 3             | 2         | 18     |
| 20A | 1       | S     | 20  | F      | 4         | 6      | 4         | None                     | 5                   | -21       | -6     | -1            | -1        | 0      |
| 20B | 2       | S     | 21  | M      | 5         | 4      | 3         | None                     | 5                   | 12        | 10     | 4             | -1        | 0      |
| 21A |         | T     | 25  | M      | 6         | 5      | 2         | None                     | 4                   | -8        | 73     | 4             | 9         | -1     |
| 21B |         | T     | 30  | M      | 5         | 4      | 2         | None                     | -48                 | 37        | 76     | 3             | 7         | 1      |
| 22A |         | T     | 22  | F      |           |        |           | None                     | 3                   | 4         | 9      | 0             | 4         | -3     |
| 22B |         | T     | 34  | M      | 6         | 6      | 4         | None                     | -25                 | -2        | 13     | 0             | 0         | 4      |
| 23A | 2       | S     | 51  | M      | 6         | 2      | 6         | Respond same time        | -7                  | 22        | -9     | -1            | 0         | -4     |
| 23B | 1       | S     | 49  | F      | 4         | 2      | 4         | None                     | 10                  | -8        | 29     | 2             | 2         | 20     |
| 24A | 1       | S     | 21  | M      | 5         | 3      | 4         | None                     | -4                  | 46        | 42     | 0             | 6         | 0      |
| 24B | 2       | S     | 20  | M      | 5         | 4      | 4         | None                     | -3                  | 7         | 41     | -1            | 4         | 14     |
| 25A |         | T     | 20  | F      | 5         | 5      | 2         | None                     | -5                  | 3         | 26     | 0             | 0         | 21     |
| 25B |         | T     | 20  | F      | 3         | 4      | 1         | None                     | -64                 | -23       | 38     | 0             | -4        | -1     |
| 26A | 2       | S     | 18  | F      | 5         | 4      | 2         | None                     | 21                  | -7        | 10     | 0             | 4         | 0      |
| 26B | 1       | S     | 18  | M      | 6         | 4      | 5         | None                     | 16                  | 12        | 6      | 0             | 0         | -2     |

|       |   |    |   |   |   |   |                     |     |     |    |    |    |     |
|-------|---|----|---|---|---|---|---------------------|-----|-----|----|----|----|-----|
| 27A   | T | 28 | M | 6 | 2 | 4 | Randomly change RTs | -21 | 12  | 2  | -1 | 2  | -1  |
| 27B   | T | 22 | M | 6 | 4 | 2 | Randomly change RTs | -8  | 9   | 15 | -2 | 0  | -18 |
| 28A   | T | 23 | M | 5 | 3 | 4 | Randomly change RTs | -3  | 34  | 10 | -1 | 0  | 11  |
| 28B   | T | 27 | M | 6 | 2 | 3 | None                | -26 | 6   | 39 | 0  | -2 | 4   |
| 29A 1 | S | 19 | M | 6 | 2 | 4 | None                | -24 | -6  | 37 | 3  | 0  | 0   |
| 29B 2 | S | 19 | F | 4 | 5 | 3 | Respond same time   | -28 | -15 | 41 | -1 | 0  | 4   |
| 30A   | T | 49 | M | 5 | 4 | 3 | None                | -18 | 8   | 49 | -1 | 11 | 1   |
| 30B   | T |    | F | 3 | 4 | 3 | None                | -15 | -14 | 11 | -2 | -3 | -1  |
| 31A 1 | S | 22 | F | 3 | 5 | 4 | Randomly change RTs | -5  | 23  | 25 | 0  | -3 | 3   |
| 31B 2 | S | 20 | F | 6 | 6 | 4 | Respond same time   | -15 | -13 | 48 | 0  | 0  | 0   |
| 32A   | T | 22 | M | 6 | 5 | 4 | None                | 4   | -8  | 8  | 0  | 0  | 4   |
| 32B   | T | 20 | F | 5 | 6 | 2 | None                | 5   | 5   | -2 | -1 | -2 | 10  |

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Table A.10. What do you know, Experiment 1 Data

| P  | Suspect | Condition | Age | Gender | Motivation | Stress | Innocence | Countermeasures            | Normalised Mean SCR |        | Normalised Mean HR |        |
|----|---------|-----------|-----|--------|------------|--------|-----------|----------------------------|---------------------|--------|--------------------|--------|
|    |         |           |     |        |            |        |           |                            | INV                 | PC     | INV                | PC     |
| 1  | G       | INV(1)    | 20  | F      | 4          | 3      | 4         | Slow Breathing             | 1.512               | -0.076 | -1.122             | -0.866 |
| 2  | G       | INV(1)    | 20  | M      | 6          | 4      | 4         | Slow Breathing             | 0.946               | 0.126  | 0.712              | -0.448 |
| 3  | G       | INV(1)    | 22  | M      | 5          | 5      | 4         | Covert Movement            | 1.525               | 0.121  | -0.682             | -0.415 |
| 4  | G       | INV(1)    | 21  | M      | 4          | 4      | 4         | Slow Breathing             | -0.252              | -0.105 | -1.240             | 0.256  |
| 5  | G       | INV(1)    | 20  | M      | 6          | 1      | 3         | Attended to controls       | 2.105               | -0.343 | -1.125             | -0.141 |
| 6  | G       | INV(1)    | 21  | F      | 6          | 1      | 2         | Covert Movement            | 0.501               | -0.574 | -0.201             | -1.419 |
| 7  | G       | INV(1)    | 21  | M      | 6          | 5      | 4         | None                       | 1.097               | -0.444 | -0.077             | -0.418 |
| 8  | G       | INV(1)    | 24  | F      | 6          | 3      | 4         | None                       | 0.385               | -0.161 | -0.815             | 0.130  |
| 9  | G       | INV(1)    | 20  | M      | 6          | 4      | 4         | None                       | 1.507               | 0.006  | -0.756             | -0.531 |
| 10 | G       | INV(1)    | 25  | F      | 6          | 2      | 6         | None                       | 0.782               | 0.476  | -0.884             | -0.047 |
| 11 | G       | INV(1)    | 21  | F      | 5          | 4      | 4         | None                       | 0.659               | 0.407  | -0.429             | -0.429 |
| 12 | G       | INV(1)    | 19  | M      | 6          | 3      | 3         | None                       | 0.744               | -0.106 | 0.630              | 0.259  |
| 13 | G       | INV(1)    | 20  | M      | 6          | 4      | 5         | Think about something else | 0.749               | -0.322 | -0.585             | 0.617  |
| 14 | G       | INV(1)    | 20  | F      | 5          | 1      | 4         | None                       | 0.993               | -0.369 | -0.568             | 0.081  |
| 15 | G       | INV(1)    | 20  | M      | 4          | 4      | 3         | Slow Breathing             | 0.416               | 0.807  | 0.023              | -0.605 |
| 16 | G       | INV(1)    | 21  | F      | 6          | 2      | 1         | None                       | 1.142               | 0.521  | 0.581              | -0.394 |
| 17 | G       | INV(1)    | 22  | F      | 6          | 3      | 1         | Attended to controls       | 0.570               | 0.658  | -0.991             | -0.782 |
| 18 | G       | INV(1)    | 20  | F      | 5          | 5      | 2         | Slow Breathing             | 1.795               | -0.528 | -0.375             | 0.078  |
| 1  | G       | PC(1)     | 21  | M      | 6          | 2      | 4         | None                       | 0.078               | 0.958  | 0.469              | -0.750 |
| 2  | G       | PC(1)     | 20  | M      | 6          | 5      | 4         | Think about something else | 1.134               | 0.283  | -0.191             | -0.721 |
| 3  | G       | PC(1)     | 21  | M      | 6          | 5      | 4         | None                       | 0.634               | 0.786  | -0.470             | -0.262 |
| 4  | G       | PC(1)     | 19  | F      | 6          | 2      | 4         | Slow Breathing             | -0.033              | 0.995  | -0.843             | 0.729  |
| 5  | G       | PC(1)     | 20  | F      | 6          | 6      | 5         | None                       | 0.389               | -0.298 | 0.203              | -1.253 |
| 6  | G       | PC(1)     | 20  | M      | 6          | 4      | 3         | Slow Breathing             | -0.247              | 1.507  | -0.192             | 0.263  |
| 7  | G       | PC(1)     | 19  | M      | 6          | 1      | 4         | Slow Breathing             | 1.707               | -0.006 | -0.925             | 0.005  |
| 8  | G       | PC(1)     | 20  | F      | 6          | 1      | 3         | None                       | 1.565               | 0.209  | -0.045             | 0.066  |
| 9  | G       | PC(1)     | 23  | F      | 6          | 2      | 5         | None                       | 1.193               | -0.561 | 0.192              | -0.550 |
| 10 | G       | PC(1)     | 18  | M      | 6          | 5      | 2         | None                       | 0.974               | 0.462  | 0.306              | -0.378 |
| 11 | G       | PC(1)     | N/A | M      | 1          | 5      | 1         | Slow Breathing             | 0.923               | -0.272 | -0.332             | -0.029 |
| 12 | G       | PC(1)     | 20  | F      | 5          | 2      | 3         | None                       | 1.190               | -0.045 | -1.101             | -0.041 |
| 13 | G       | PC(1)     | 45  | M      | 5          | 5      |           | Slow Breathing             | 0.383               | 0.607  | 1.404              | 0.116  |
| 14 | G       | PC(1)     | 21  | M      | 5          | 4      | 4         | Attended to controls       | 0.053               | 1.226  | -0.941             | -0.602 |
| 15 | G       | PC(1)     | 19  | F      | 6          | 5      | 3         | Slow Breathing             | 0.458               | 1.187  | -1.374             | 0.163  |
| 16 | G       | PC(1)     | 22  | F      | 5          | 3      | 2         | None                       | 1.189               | -0.472 | -0.597             | 0.327  |
| 17 | G       | PC(1)     | 21  | F      | 6          | 2      | 5         | Think about something else | 0.629               | -0.166 | -1.042             | -0.404 |
| 18 | G       | PC(1)     | 20  | M      | 5          | 3      | 2         | Slow Breathing             | 1.694               | 0.123  | 0.137              | -0.146 |
| 1  | I       | INV(1)    | 22  | M      | 5          | 4      | 6         | None                       | -0.183              | -0.345 | -0.217             | -0.006 |
| 2  | I       | INV(1)    | 22  | F      | 4          | 1      | 4         | None                       | 0.390               | -0.097 | 0.896              | -0.569 |
| 3  | I       | INV(1)    | 20  | F      | 4          | 4      | 3         | None                       | 0.290               | -0.147 | 0.355              | -0.929 |
| 4  | I       | INV(1)    | 19  | M      | 5          | 1      | 5         | None                       | -0.332              | 0.862  | 0.438              | -0.106 |
| 5  | I       | INV(1)    | 21  | M      | 5          | 3      | 3         | None                       | -0.324              | -0.057 | -0.137             | 0.327  |
| 6  | I       | INV(1)    | 22  | F      | 5          | 2      | 5         | None                       | 0.093               | -0.162 | -0.053             | 0.351  |
| 7  | I       | INV(1)    | 21  | F      | 4          | 2      | 3         | None                       | 0.211               | -0.247 | 0.155              | -0.371 |
| 8  | I       | INV(1)    | 20  | M      | 6          | 4      | 6         | None                       | -0.209              | -0.084 | -0.224             | -0.310 |
| 9  | I       | INV(1)    | 21  | F      | 5          | 2      | 5         | None                       | -0.163              | 0.060  | -0.075             | -0.858 |
| 10 | I       | INV(1)    | 19  | M      | 5          | 4      | 2         | None                       | -0.247              | -0.036 | -0.410             | 0.773  |
| 11 | I       | INV(1)    | 20  | M      | 4          | 3      | 4         | None                       | -0.330              | -0.091 | 0.301              | -0.699 |
| 12 | I       | INV(1)    | 23  | M      | 5          | 2      | 3         | None                       | 0.310               | 0.804  | -0.429             | 0.430  |

|    |   |        |    |   |   |   |   |      |        |        |        |        |
|----|---|--------|----|---|---|---|---|------|--------|--------|--------|--------|
| 13 | I | INV(1) | 21 | M | 5 | 3 | 5 | None | 0.044  | -0.453 | -0.318 | -0.192 |
| 14 | I | INV(1) | 19 | M | 5 | 2 | 5 | None | -0.239 | 1.671  | -0.212 | -0.750 |
| 15 | I | PC(1)  | 21 | F | 4 | 1 | 5 | None |        |        |        |        |
| 16 | I | INV(1) | 20 | F | 6 | 4 | 6 | None | 0.540  | 1.197  | 0.550  | -0.497 |
| 17 | I | INV(1) | 21 | M | 5 | 4 | 4 | None | 0.114  | -0.352 | 0.565  | 0.898  |
| 18 | I | INV(1) | 21 | F | 5 | 4 | 5 | None | 0.116  | -0.257 | 0.839  | -0.165 |
| 19 | I | INV(1) | 19 | M | 5 | 4 | 5 | None | -0.920 | 0.500  | 0.043  | 0.944  |
| 1  | I | PC(1)  | 21 | M | 6 | 0 | 3 | None | -0.176 | -0.478 | 0.089  | 0.401  |
| 2  | I | PC(1)  | 21 | F | 5 | 2 | 4 | None | 0.012  | -0.677 | 0.801  | -0.573 |
| 3  | I | PC(1)  | 21 | M | 6 | 3 | 2 | None | 0.048  | -0.529 | 1.341  | -0.652 |
| 4  | I | PC(1)  | 20 | F | 6 | 3 | 4 | None |        |        | 0.297  | -0.578 |
| 5  | I | PC(1)  | 22 | M | 4 | 2 | 2 | None | 0.730  | -0.679 | -0.483 | 0.386  |
| 6  | I | PC(1)  | 19 | F | 6 | 2 | 5 | None | -0.329 | -0.313 | -0.399 | 0.351  |
| 7  | I | PC(1)  | 24 | F | 6 | 3 | 1 | None | -0.419 | -0.359 | -1.239 | 0.343  |
| 8  | I | PC(1)  | 21 | M | 3 | 0 | 5 | None |        |        | -0.214 | -0.271 |
| 9  | I | PC(1)  | 19 | M | 5 | 4 | 4 | None | 0.452  | -0.283 | -0.217 | -0.624 |
| 10 | I | PC(1)  | 20 | F | 6 | 2 | 4 | None | -0.186 | 1.228  | -0.614 | -0.055 |
| 11 | I | PC(1)  | 20 | M | 4 | 2 | 3 | None | 0.391  | -0.698 | -0.226 | 0.488  |
| 12 | I | PC(1)  | 22 | F | 6 | 4 | 1 | None | -0.118 | -0.287 | -0.312 | 0.243  |
| 13 | I | PC(1)  | 22 | F | 6 | 4 | 6 | None | -0.229 | 0.003  | -0.286 | 0.561  |
| 14 | I | PC(1)  | 20 | M | 5 | 2 | 3 | None | -0.095 | 0.070  | -0.858 | 0.351  |
| 15 | I | PC(1)  | 18 | M | 4 | 1 | 5 | None |        |        | -0.365 | 0.138  |
| 16 | I | PC(1)  | 20 | M | 5 | 2 | 6 | None | -0.049 | -0.516 | 0.573  | -0.199 |
| 17 | I | PC(1)  | 23 | M | 4 | 3 | 4 | None | -0.259 | -0.274 | -0.819 | 0.031  |

Table A.11. What do you know, Experiment 2 Data

| P  | Suspect | Condition | Age | Gender | Motivation | Stress | Innocence | Countermeasures            | Normalised<br>Mean SCR | Normalised<br>Mean HR |
|----|---------|-----------|-----|--------|------------|--------|-----------|----------------------------|------------------------|-----------------------|
| 1  | G       | INV       | 21  | F      | 5          | 1      | 4         | None                       | 0.442                  | -0.253                |
| 2  | G       | INV       | 20  | F      | 4          | 4      | 2         | None                       | 0.433                  | -0.690                |
| 3  | G       | INV       | 21  | F      | 5          | 2      | 5         | Attended to controls       | 0.702                  | -0.242                |
| 4  | G       | INV       | 23  | M      | 6          | 4      | 5         | None                       | 0.213                  | -0.578                |
| 5  | G       | INV       | 20  | M      | 6          | 5      | 4         | Heart Rate                 | 0.561                  | 0.093                 |
| 6  | G       | INV       | 19  | F      | 5          | 6      | 3         | None                       | 0.275                  | -0.549                |
| 7  | G       | INV       | 19  | M      | 5          | 2      | 4         | Breathing                  |                        | 0.112                 |
| 8  | G       | INV       | 20  | F      | 5          | 3      | 4         | Think about something else | 1.034                  | 0.061                 |
| 9  | G       | INV       | 22  | M      | 4          | 4      | 4         | None                       | 0.827                  | -1.060                |
| 10 | G       | INV       | 21  | F      | 4          | 2      | 3         | None                       | 0.435                  | -0.280                |
| 11 | G       | INV       | 19  | M      | 6          | 4      | 4         | None                       | 0.449                  | -0.670                |
| 12 | G       | INV       | 20  | F      | 6          | 6      | 2         | None                       | 0.970                  | -0.406                |
| 13 | G       | INV       | 20  | F      | 6          | 4      | 3         | Breathing                  | 0.294                  | 0.119                 |
| 14 | G       | INV       | 32  | M      | 6          | 4      | 3         | Breathing                  | 1.176                  | -0.126                |
| 15 | G       | INV       | 20  | F      | 5          | 4      | 2         | None                       | 1.114                  | -0.479                |
| 16 | G       | INV       | 20  | F      | 6          | 5      | 2         | Covert Movement            | 1.027                  | 0.059                 |
| 17 | G       | INV       | 19  | M      | 6          | 4      | 4         | Heart Rate                 | 0.471                  | -0.913                |
| 18 | G       | INV       | 22  | M      | 6          | 4      | 6         | Think about something else | 0.663                  | -0.147                |
| 19 | G       | INV       | 19  | M      | 5          | 4      | 5         | Breathing                  | 0.434                  | -0.252                |
| 1  | G       | PC        | 20  | F      | 5          | 3      | 3         | Breathing                  | 0.105                  | 0.152                 |
| 2  | G       | PC        | 22  | F      | 3          | 2      | 2         | None                       | 1.033                  | -0.343                |
| 3  | G       | PC        | 21  | F      | 6          | 1      | 4         | Calm                       | -0.037                 | -0.330                |
| 4  | G       | PC        | 21  | F      | 5          | 3      | 3         | None                       | 0.421                  | -0.667                |
| 5  | G       | PC        | 21  | F      | 4          | 1      | 2         | None                       | 0.284                  | 0.122                 |
| 6  | G       | PC        | 21  | F      | 5          | 5      | 3         | None                       | 0.001                  | -0.003                |
| 7  | G       | PC        | 20  | F      | 6          | 4      | 2         | Attended to controls       | 0.834                  | -0.114                |
| 8  | G       | PC        | 22  | F      | 5          | 4      | 3         | None                       | 0.572                  | -0.005                |
| 9  | G       | PC        | 21  | F      | 5          | 2      | 5         | None                       | 0.343                  | 0.110                 |
| 10 | G       | PC        | 20  | F      | 6          | 5      | 3         | None                       | -0.048                 | -0.249                |
| 11 | G       | PC        | 20  | F      | 6          | 6      | 3         | Breathing                  | 0.337                  | 0.305                 |
| 12 | G       | PC        | 21  | F      | 5          | 1      | 5         | None                       | 0.192                  | -0.135                |
| 13 | G       | PC        | 19  | M      | 5          | 1      | 3         | Think about something else | 0.063                  | -0.708                |
| 14 | G       | PC        | 20  | F      | 5          | 4      | 3         | Breathing                  | 0.276                  | -0.663                |
| 15 | G       | PC        | 21  | F      | 5          | 4      | 2         | Calm                       | 0.922                  | -0.596                |
| 16 | G       | PC        | 19  | F      | 4          | 4      | 3         | None                       | 0.518                  | -0.370                |
| 17 | G       | PC        | 22  | M      | 5          | 2      | 4         | Breathing                  | 0.306                  | -0.626                |
| 18 | G       | PC        | 20  | M      | 4          | 3      | 4         | None                       | 0.785                  | -0.052                |
| 19 | G       | PC        | 20  | M      | 5          | 5      | 4         | Breathing                  | 0.525                  | -0.190                |
| 1  | I       | INV       | 21  | F      | 4          | 2      | 3         | None                       | -0.170                 | 0.008                 |
| 2  | I       | INV       | 19  | F      | 3          | 2      | 3         | None                       | 0.741                  | -0.357                |
| 3  | I       | INV       | 21  | F      | 5          | 2      | 5         | None                       | -0.156                 | -0.313                |
| 4  | I       | INV       | 19  | F      | 4          | 2      | 2         | None                       | -0.495                 | -0.253                |
| 5  | I       | INV       | 20  | F      | 5          | 1      | 5         | None                       | -0.340                 | -0.198                |
| 6  | I       | INV       | 20  | F      | 5          | 2      | 3         | None                       | -0.128                 | 0.511                 |
| 7  | I       | INV       | 21  | F      | 4          | 4      | 3         | None                       | -0.069                 | -0.435                |
| 8  | I       | INV       | 20  | M      | 6          | 1      | 4         | None                       | 0.576                  | -0.226                |
| 9  | I       | INV       | 21  | M      | 6          | 3      | 2         | None                       | -0.147                 | 0.390                 |
| 10 | I       | INV       | 20  | F      | 5          | 2      | 4         | None                       |                        |                       |
| 11 | I       | INV       | 22  | M      | 5          | 3      | 4         | None                       | -0.120                 | -0.020                |
| 12 | I       | INV       | 22  | F      | 3          | 3      | 5         | None                       | 0.248                  | -0.522                |
| 13 | I       | INV       | 19  | M      | 5          | 2      | 5         | None                       | -0.255                 | 0.111                 |
| 14 | I       | INV       | 19  | F      | 5          | 4      | 3         | None                       | 0.464                  | -0.684                |
| 15 | I       | INV       | 21  | M      | 4          | 2      | 2         | None                       | 0.027                  | -0.394                |

|    |   |     |    |   |   |   |   |      |        |        |
|----|---|-----|----|---|---|---|---|------|--------|--------|
| 16 | I | INV | 20 | F | 5 | 5 | 4 | None | -0.177 | 0.250  |
| 17 | I | INV | 20 | M | 6 | 1 | 5 | None | 0.326  | -0.403 |
| 18 | I | INV | 21 | F | 6 | 5 | 3 | None | 0.324  | -0.261 |
| 19 | I | INV | 20 | F | 5 | 2 | 5 | None | -0.286 | -0.042 |
| 20 | I | INV | 21 | F | 5 | 4 | 5 | None | 0.278  | 0.083  |
| 1  | I | PC  | 20 | F | 5 | 3 | 6 | None | 0.460  | -0.330 |
| 2  | I | PC  | 20 | F | 5 | 1 | 6 | None | 0.434  | 0.277  |
| 3  | I | PC  | 21 | F | 3 | 2 | 4 | None | 0.405  | -0.064 |
| 4  | I | PC  | 21 | F | 5 | 1 | 4 | None | -0.054 | -0.732 |
| 5  | I | PC  | 19 | F | 5 | 2 | 5 | None | 0.552  | 0.286  |
| 6  | I | PC  | 20 | M | 3 | 3 | 4 | None | -0.325 | 0.219  |
| 7  | I | PC  | 22 | F | 6 | 4 | 6 | None | 0.059  | -0.350 |
| 8  | I | PC  | 21 | M | 3 | 3 | 6 | None | 0.212  | 0.076  |
| 9  | I | PC  | 21 | F | 5 | 1 | 6 | None | 0.079  | 0.345  |
| 10 | I | PC  | 19 | F | 5 | 4 | 3 | None | -0.301 | -0.349 |
| 11 | I | PC  | 23 | F | 6 | 2 | 5 | None | -0.309 | 0.137  |
| 12 | I | PC  | 20 | F | 5 | 1 | 6 | None | 0.703  | 0.329  |
| 13 | I | PC  | 21 | F | 5 | 1 | 5 | None | 0.424  | -0.148 |
| 14 | I | PC  | 20 | F | 3 | 4 | 6 | None | -0.091 | 0.005  |
| 15 | I | PC  | 21 | F | 4 | 1 | 5 | None | 0.353  | -0.230 |
| 16 | I | PC  | 20 | F | 5 | 2 | 4 | None |        |        |
| 17 | I | PC  | 21 | M | 5 | 2 | 4 | None |        |        |
| 18 | I | PC  | 20 | F | 5 | 3 | 4 | None | 0.107  | 0.203  |
| 19 | I | PC  | 22 | M | 6 | 4 | 5 | None | 0.089  | -0.527 |
| 20 | I | PC  | 24 | M | 4 | 2 | 6 | None | 0.203  | 0.133  |
| 21 | I | PC  | 22 | M | 4 | 1 | 3 | None | 0.023  | 0.307  |
| 22 | I | PC  | 21 | F | 6 | 4 | 5 | None | -0.107 | 0.293  |

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Table A.12. Caught Virtually Lying, Experiment 1 Data

| P  | Suspect | Modality | Age | Gender | VR Before | Motivation | Crime Stress | Stress | Countermeasure             | Normalised<br>Mean SCR |        | Normalised<br>Mean HR |        |
|----|---------|----------|-----|--------|-----------|------------|--------------|--------|----------------------------|------------------------|--------|-----------------------|--------|
|    |         |          |     |        |           |            |              |        |                            | Control                | Crime  | Control               | Crime  |
| 1  | G       | PC       | 27  | F      |           | 5          | 6            | 5      | Think about something else | -0.092                 | 0.184  | 0.243                 | -0.487 |
| 2  | G       | PC       | 19  | M      |           | 5          | 3            | 3      | Think about something else | 0.055                  | -0.111 | -0.106                | 0.212  |
| 3  | G       | PC       | 27  | F      |           | 6          | 4            | 4      | Slow Breathing             | 0.130                  | -0.259 | 0.427                 | -0.854 |
| 4  | G       | PC       | 19  | F      |           | 5          | 1            | 2      | None                       | -0.007                 | 0.014  | 0.178                 | -0.357 |
| 5  | G       | PC       | 18  | M      |           | 6          | 5            | 3      | Think about something else | -0.079                 | 0.159  |                       |        |
| 6  | G       | PC       | 22  | F      |           | 4          | 2            | 2      | None                       | -0.364                 | 0.727  | -0.101                | 0.201  |
| 7  | G       | PC       | 18  | M      |           | 6          | 1            | 1      | None                       | -0.107                 | 0.215  | 0.296                 | -0.592 |
| 8  | G       | PC       | 18  | M      |           | 5          | 5            | 5      | None                       | 0.003                  | -0.006 | 0.202                 | -0.403 |
| 9  | G       | PC       | 22  | F      |           | 4          | 4            | 4      | Slow Breathing             | -0.266                 | 0.533  | -0.041                | 0.082  |
| 10 | G       | PC       | 21  | F      |           | 5          | 3            | 3      | None                       | -0.356                 | 0.712  | 0.332                 | -0.665 |
| 11 | G       | PC       | 19  | F      |           | 5          | 3            | 3      | Think about something else | 0.013                  | -0.027 | 0.187                 | -0.375 |
| 12 | G       | PC       | 19  | F      |           | 6          | 4            | 2      | Slow Breathing             | -0.116                 | 0.217  | 0.207                 | -0.389 |
| 13 | G       | PC       | 21  | F      |           | 5          | 3            | 2      | Stay Calm                  | -0.187                 | 0.374  | 0.289                 | -0.578 |
| 14 | G       | PC       | 19  | M      |           | 5          | 2            | 3      | Think about something else | -0.153                 | 0.305  | 0.162                 | -0.323 |
| 15 | G       | PC       | 20  | F      |           | 6          | 5            | 5      | None                       | -0.092                 | 0.183  | 0.080                 | -0.161 |
| 16 | G       | PC       | 21  | M      |           | 6          | 4            | 3      | Slow Breathing             | -0.131                 | 0.262  | 0.169                 | -0.339 |
| 17 | G       | PC       | 23  | F      |           | 5          | 2            | 2      | None                       | -0.265                 | 0.529  | -0.051                | 0.101  |
| 18 | G       | PC       | 21  | F      |           | 5          | 3            | 2      | None                       | -0.189                 | 0.378  | -0.051                | 0.102  |
| 19 | G       | PC       | 18  | F      |           | 4          | 3            | 4      | Slow Breathing             | 0.096                  | -0.192 | -0.106                | 0.212  |
| 20 | G       | PC       | 20  | M      |           | 6          | 4            | 2      | None                       | -0.026                 | 0.052  | 0.026                 | -0.052 |
| 21 | G       | PC       | 18  | F      |           | 6          | 2            | 3      | None                       | -0.045                 | 0.084  | 0.061                 | -0.114 |
| 22 | G       | PC       | 18  | M      |           | 5          | 2            | 2      | Slow Breathing             | -0.076                 | 0.151  | 0.208                 | -0.415 |
| 23 | G       | PC       | 20  | F      |           | 4          | 4            | 2      | None                       | -0.222                 | 0.415  | -0.200                | 0.375  |
| 24 | G       | PC       | 19  | F      |           | 6          | 1            | 1      | None                       | 0.051                  | -0.102 | -0.016                | 0.032  |
| 25 | G       | PC       | 20  | M      |           | 5          | 4            | 2      | None                       | -0.323                 | 0.646  | 0.195                 | -0.391 |
| 26 | G       | PC       | 23  | M      |           | 5          | 4            | 4      | Slow Breathing             | -0.026                 | 0.049  | 0.058                 | -0.110 |
| 27 | G       | PC       | 20  | F      |           | 6          | 3            | 3      | Slow Breathing             | -0.257                 | 0.515  | 0.183                 | -0.366 |
| 28 | G       | PC       | 22  | F      |           | 5          | 4            | 4      | None                       | 0.125                  | -0.203 | 0.318                 | -0.517 |
| 29 | G       | PC       | 18  | M      |           | 5          | 4            | 4      | None                       | 0.003                  | -0.005 | -0.253                | 0.505  |
| 30 | G       | PC       | 19  | M      |           | 6          | 3            | 3      | Think about something else | -0.027                 | 0.054  | 0.257                 | -0.514 |
| 31 | G       | PC       | 20  | F      |           | 5          | 6            | 6      | None                       | 0.012                  | -0.024 | -0.209                | 0.417  |
| 32 | G       | PC       | 19  | M      |           | 6          | 1            | 1      | None                       | -0.280                 | 0.560  | -0.106                | 0.212  |
| 33 | G       | VR       | 21  | F      | N         | 4          | 3            | 5      | Slow Breathing             | -0.139                 | 0.278  | 0.207                 | -0.415 |
| 34 | G       | VR       | 19  | F      | Y         | 4          | 4            | 4      | None                       | -0.292                 | 0.585  | -0.028                | 0.055  |
| 35 | G       | VR       | 18  | F      | N         | 5          | 6            | 5      | Slow Breathing             | -0.188                 | 0.376  | 0.009                 | -0.017 |
| 36 | G       | VR       | 21  | F      | Y         | 5          | 2            | 2      | None                       | -0.089                 | 0.177  | 0.041                 | -0.082 |
| 37 | G       | VR       | 20  | M      | Y         | 6          | 2            | 2      | Think about something else | -0.311                 | 0.623  | 0.066                 | -0.133 |
| 38 | G       | VR       | 21  | M      | Y         | 5          | 3            | 3      | None                       | -0.232                 | 0.463  |                       |        |
| 39 | G       | VR       | 21  | M      | Y         | 6          | 1            | 1      | None                       | -0.147                 | 0.295  | 0.063                 | -0.125 |
| 40 | G       | VR       | 20  | M      | N         | 6          | 1            | 1      | None                       | -0.355                 | 0.710  | -0.009                | 0.018  |
| 41 | G       | VR       | 24  | M      | N         | 5          | 1            | 3      | None                       | -0.028                 | 0.055  | -0.058                | 0.116  |
| 42 | G       | VR       | 20  | F      | N         | 4          | 5            | 3      | None                       | -0.351                 | 0.701  | 0.148                 | -0.296 |
| 43 | G       | VR       | 22  | M      | N         | 6          | 5            | 2      | Slow Breathing             | 0.126                  | -0.236 | 0.280                 | -0.526 |
| 44 | G       | VR       | 35  | M      | Y         | 5          | 4            | 4      | Slow Breathing             | -0.283                 | 0.565  | 0.178                 | -0.356 |
| 45 | G       | VR       | 20  | M      | N         | 5          | 5            | 2      | None                       | -0.207                 | 0.413  | 0.148                 | -0.296 |
| 46 | G       | VR       | 21  | F      | Y         | 5          | 1            | 2      | None                       | -0.245                 | 0.489  |                       |        |
| 47 | G       | VR       | 20  | M      | N         | 4          | 4            | 4      | None                       | -0.004                 | 0.008  | 0.347                 | -0.694 |
| 48 | G       | VR       | 21  | F      | N         | 5          | 4            | 4      | Slow Breathing             | -0.142                 | 0.284  | -0.035                | 0.070  |
| 49 | G       | VR       | 22  | M      | N         | 6          | 6            | 5      | Slow Breathing             | -0.197                 | 0.394  | 0.253                 | -0.507 |
| 50 | G       | VR       | 18  | M      | N         | 6          | 1            | 4      | Slow Breathing             | -0.225                 | 0.421  | -0.212                | 0.397  |

|     |   |    |    |   |   |   |   |   |                            |        |        |        |        |
|-----|---|----|----|---|---|---|---|---|----------------------------|--------|--------|--------|--------|
| 51  | G | VR | 18 | M | Y | 5 | 1 | 1 | None                       | -0.204 | 0.408  | 0.302  | -0.604 |
| 52  | G | VR | 18 | F | Y | 5 | 5 | 4 | None                       | -0.201 | 0.402  | 0.275  | -0.550 |
| 53  | G | VR | 20 | M | Y | 5 | 1 | 1 | Think about something else | -0.175 | 0.349  | -0.253 | 0.507  |
| 54  | G | VR | 22 | M | N | 5 | 5 | 6 | Think about something else | -0.193 | 0.385  | -0.015 | 0.029  |
| 55  | G | VR | 19 | F | N | 6 | 2 | 1 | None                       | -0.340 | 0.680  | -0.097 | 0.195  |
| 56  | G | VR | 19 | M | Y | 6 | 2 | 3 | None                       | 0.019  | -0.038 | 0.209  | -0.418 |
| 57  | G | VR | 19 | F | Y | 6 | 2 | 2 | Slow Breathing             | -0.377 | 0.755  | 0.053  | -0.105 |
| 58  | G | VR | 46 | F | N | 4 | 2 | 2 | None                       | -0.161 | 0.322  | -0.063 | 0.127  |
| 59  | G | VR | 22 | F | Y | 5 | 5 | 3 | None                       | -0.210 | 0.421  | 0.093  | -0.186 |
| 60  | G | VR | 19 | F | Y | 6 | 1 | 1 | None                       | -0.142 | 0.284  | 0.272  | -0.543 |
| 61  | G | VR | 32 | F | N | 6 | 6 | 5 | None                       | -0.454 | 0.907  |        |        |
| 62  | G | VR | 21 | F | N | 6 | 1 | 1 | None                       | -0.224 | 0.449  | -0.262 | 0.524  |
| 63  | G | VR | 28 | F | Y | 3 | 5 | 5 | None                       | -0.377 | 0.754  | 0.165  | -0.330 |
| 64  | G | VR | 27 | M | Y | 5 | 2 | 3 | None                       | -0.255 | 0.510  | 0.309  | -0.619 |
| 65  | I | PC | 18 | F |   | 5 |   | 1 | None                       | 0.013  | -0.026 | -0.042 | 0.085  |
| 66  | I | PC | 19 | M |   | 6 |   | 3 | None                       | 0.114  | -0.227 | 0.160  | -0.319 |
| 67  | I | PC | 23 | F |   | 6 |   | 2 | None                       | -0.261 | 0.521  | 0.143  | -0.287 |
| 68  | I | PC | 20 | M |   | 3 |   | 1 | None                       | 0.054  | -0.109 |        |        |
| 69  | I | PC | 18 | F |   | 5 |   | 1 | None                       | -0.029 | 0.059  | -0.037 | 0.073  |
| 70  | I | PC | 22 | M |   | 4 |   | 2 | None                       | -0.044 | 0.100  |        |        |
| 71  | I | PC | 22 | M |   | 4 |   | 2 | None                       |        |        | 0.153  | -0.306 |
| 72  | I | PC | 21 | F |   | 5 |   | 2 | None                       | -0.037 | 0.075  | -0.122 | 0.244  |
| 73  | I | PC | 19 | F |   | 5 |   | 2 | None                       | -0.025 | 0.051  | -0.196 | 0.392  |
| 74  | I | PC | 19 | M |   | 3 |   | 2 | None                       |        |        | -0.013 | 0.027  |
| 75  | I | PC | 19 | F |   | 6 |   | 4 | None                       | 0.038  | -0.076 | 0.100  | -0.200 |
| 76  | I | PC | 19 | F |   | 4 |   | 3 | None                       | -0.041 | 0.082  | -0.089 | 0.177  |
| 77  | I | PC | 22 | F |   | 4 |   | 4 | None                       | 0.087  | -0.173 | -0.228 | 0.457  |
| 78  | I | PC | 19 | F |   | 6 |   | 1 | None                       | -0.025 | 0.050  | -0.075 | 0.150  |
| 79  | I | PC | 18 | M |   | 5 |   | 1 | None                       | 0.045  | -0.090 | -0.092 | 0.183  |
| 80  | I | PC | 19 | F |   | 6 |   | 1 | None                       |        |        | 0.125  | -0.250 |
| 81  | I | PC | 20 | M |   | 3 |   | 1 | None                       | -0.122 | 0.391  | -0.087 | 0.278  |
| 82  | I | PC | 18 | F |   | 6 |   | 1 | None                       | -0.167 | 0.333  | 0.154  | -0.309 |
| 83  | I | PC | 21 | F |   | 4 |   | 2 | None                       | 0.085  | -0.149 | 0.005  | -0.008 |
| 84  | I | PC | 25 | M |   | 4 |   | 3 | None                       | 0.045  | -0.090 | 0.030  | -0.060 |
| 85  | I | PC | 23 | F |   | 5 |   | 1 | None                       | 0.184  | -0.368 | -0.041 | 0.082  |
| 86  | I | PC | 18 | F |   | 4 |   | 1 | None                       | 0.035  | -0.070 | -0.006 | 0.012  |
| 87  | I | PC | 20 | F |   | 4 |   | 2 | None                       | 0.120  | -0.240 | -0.210 | 0.420  |
| 88  | I | PC | 23 | F |   | 3 |   | 1 | None                       | 0.029  | -0.057 | -0.305 | 0.610  |
| 89  | I | PC | 25 | F |   | 5 |   | 1 | None                       | 0.077  | -0.145 | -0.183 | 0.342  |
| 90  | I | PC | 18 | F |   | 4 |   | 2 | None                       | -0.235 | 0.470  | -0.013 | 0.026  |
| 91  | I | PC | 18 | M |   | 5 |   | 1 | None                       | 0.087  | -0.174 | 0.193  | -0.387 |
| 92  | I | PC | 18 | F |   | 5 |   | 2 | None                       | 0.119  | -0.237 | -0.029 | 0.058  |
| 93  | I | PC | 22 | F |   | 5 |   | 1 | None                       | 0.184  | -0.368 | 0.178  | -0.357 |
| 94  | I | PC | 39 | F |   | 4 |   | 4 | None                       | -0.134 | 0.269  | 0.049  | -0.098 |
| 95  | I | PC | 19 | M |   | 4 |   | 2 | None                       | -0.082 | 0.187  | 0.264  | -0.604 |
| 96  | I | PC | 22 | F |   | 5 |   | 1 | None                       |        |        | -0.051 | 0.102  |
| 97  | I | VR | 23 | F | Y | 5 |   | 2 | None                       | 0.200  | -0.400 | 0.006  | -0.013 |
| 98  | I | VR | 21 | F | N | 5 |   | 1 | None                       | 0.102  | -0.204 | 0.072  | -0.144 |
| 99  | I | VR | 20 | M | Y | 6 |   | 2 | None                       | 0.168  | -0.336 | -0.007 | 0.014  |
| 100 | I | VR | 23 | F | N | 5 |   | 2 | None                       | -0.081 | 0.162  | -0.124 | 0.248  |
| 101 | I | VR | 21 | M | N | 5 |   | 2 | None                       | 0.129  | -0.259 | 0.236  | -0.471 |
| 102 | I | VR | 24 | F | N | 5 |   | 1 | None                       | -0.149 | 0.299  | 0.015  | -0.029 |
| 103 | I | VR | 21 | M | Y | 5 |   | 1 | None                       | 0.022  | -0.044 | -0.127 | 0.253  |
| 104 | I | VR | 21 | F | N | 5 |   | 1 | None                       | 0.030  | -0.060 | 0.097  | -0.195 |
| 105 | I | VR | 19 | F | N | 5 |   | 4 | None                       | 0.131  | -0.262 | 0.119  | -0.238 |
| 106 | I | VR | 22 | F | Y | 4 |   | 3 | None                       | -0.089 | 0.177  | -0.101 | 0.203  |
| 107 | I | VR | 20 | F | N | 4 |   | 2 | None                       | 0.084  | -0.168 | -0.100 | 0.200  |
| 108 | I | VR | 20 | F | Y | 2 |   | 1 | None                       | 0.072  | -0.144 | -0.227 | 0.454  |
| 109 | I | VR | 22 | F | Y | 4 |   | 2 | None                       | -0.111 | 0.221  | -0.081 | 0.162  |
| 110 | I | VR | 21 | F | N | 4 |   | 4 | None                       | 0.103  | -0.206 | 0.253  | -0.505 |

|     |   |    |    |   |   |   |   |      |        |        |        |        |
|-----|---|----|----|---|---|---|---|------|--------|--------|--------|--------|
| 111 | I | VR | 18 | M | Y | 4 | 1 | None | 0.124  | -0.247 | 0.084  | -0.169 |
| 112 | I | VR | 18 | M | N | 5 | 6 | None | 0.183  | -0.366 | 0.300  | -0.599 |
| 113 | I | VR | 19 | F | Y | 4 | 5 | None | -0.044 | 0.087  | -0.118 | 0.236  |
| 114 | I | VR | 24 | M | Y | 5 | 3 | None | 0.145  | -0.291 | 0.140  | -0.279 |
| 115 | I | VR | 19 | F | N | 5 | 1 | None | 0.005  | -0.009 | -0.002 | 0.005  |
| 116 | I | VR | 20 | M | Y | 4 | 3 | None | 0.100  | -0.201 | -0.078 | 0.156  |
| 117 | I | VR | 32 | F | Y | 6 | 1 | None | 0.183  | -0.366 | -0.226 | 0.452  |
| 118 | I | VR | 21 | F | N | 5 | 1 | None |        |        | -0.128 | 0.255  |
| 119 | I | VR | 20 | F | N | 4 | 2 | None | -0.052 | 0.120  | 0.063  | -0.145 |
| 120 | I | VR | 19 | M | N | 5 | 2 | None | -0.127 | 0.255  | 0.036  | -0.073 |
| 121 | I | VR | 21 | M | N | 4 | 2 | None | -0.167 | 0.333  | 0.031  | -0.063 |
| 122 | I | VR | 18 | M | N | 4 | 2 | None | 0.095  | -0.218 | 0.123  | -0.282 |
| 123 | I | VR | 18 | M | N | 6 | 3 | None | -0.012 | 0.025  | 0.241  | -0.482 |
| 124 | I | VR | 19 | M | Y | 6 | 3 | None | 0.109  | -0.218 | -0.130 | 0.260  |
| 125 | I | VR | 18 | M | N | 5 | 3 | None | -0.136 | 0.271  | 0.029  | -0.058 |
| 126 | I | VR | 18 | F | N | 5 | 1 | None | -0.366 | 0.687  | -0.147 | 0.275  |
| 127 | I | VR | 20 | M | N | 6 | 2 | None | -0.134 | 0.269  | -0.094 | 0.188  |
| 128 | I | VR | 19 | F | N | 4 | 3 | None | 0.008  | -0.015 | -0.197 | 0.393  |

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Table A.13. *Fading Memories, Experiment 1 Data*

| P  | Condition | Delay | Age | Gender | Motivation | Stress | Innocence | Normalised Mean SCR        |        |                       |
|----|-----------|-------|-----|--------|------------|--------|-----------|----------------------------|--------|-----------------------|
|    |           |       |     |        |            |        |           | Countermeasure             | All    | Without Memory Errors |
| 1  | Short     | 3     | 20  | F      | 6          | 3      | 5         | None                       | 0.088  | 0.088                 |
| 2  | Short     | 2     | 21  | F      | 5          | 1      | 3         | None                       | 0.528  | 0.528                 |
| 3  | Long      | 71    | 19  | F      | 4          | 2      | 2         | None                       | 0.042  | 0.042                 |
| 4  | Long      | 72    | 21  | F      | 6          | 3      | 1         | None                       | 0.095  | 0.095                 |
| 5  | Short     | 3     | 19  | M      | 2          | 3      | 4         | None                       | 0.391  | 0.391                 |
| 6  | Short     | 1     | 23  | F      | 5          | 4      | 2         | None                       | 0.690  | 0.690                 |
| 7  | Short     | 3     | 19  | M      | 6          | 2      | 3         | None                       | 0.181  | 0.181                 |
| 8  | Short     | 4     | 18  | M      | 4          | 1      | 1         | None                       |        |                       |
| 9  | Short     | 3     | 27  | F      | 4          | 2      | 2         | None                       | 0.885  | 0.885                 |
| 10 | Short     | 6     | 18  | F      | 5          | 4      | 3         | Slow Breathing             | 0.893  | 0.893                 |
| 11 | Short     | 4     | 20  | F      | 6          | 3      | 2         | None                       | -0.081 | -0.081                |
| 12 | Short     | 3     | 19  | F      | 5          | 2      | 1         | Think about something else | 0.284  | 0.284                 |
| 13 | Short     | 3     | 19  | M      | 4          | 1      | 2         | None                       | 0.730  | 0.730                 |
| 14 | Short     | 5     | 18  | F      | 3          | 2      | 2         | Slow Breathing             | 0.570  | 0.570                 |
| 15 | Short     | 8     | 18  | F      | 4          | 2      | 2         | None                       | 0.725  | 0.725                 |
| 17 | Short     | 8     | 19  | M      | 4          | 3      | 3         | None                       | 0.088  | 0.088                 |
| 18 | Short     | 2     | 18  | M      | 5          | 4      | 1         | None                       | 0.191  | 0.191                 |
| 19 | Short     | 2     | 20  | F      | 6          | 1      | 1         | None                       | 0.219  | 0.219                 |
| 20 | Short     | 2     | 18  | M      | 3          | 1      | 3         | None                       | 0.027  | 0.027                 |
| 21 | Short     | 3     | 18  | F      | 4          | 2      | 2         | Think about something else | 0.405  | 0.405                 |
| 22 | Long      | 63    | 21  | M      | 3          | 4      | 6         | None                       | 0.565  | 0.565                 |
| 23 | Short     | 2     | 20  | F      | 5          | 5      | 4         | None                       |        |                       |
| 24 | Long      | 75    | 20  | M      | 3          | 6      | 5         | None                       | -0.013 | -0.303                |
| 25 | Short     | 1     | 26  | M      | 6          | 1      | 3         | Attended to controls       |        |                       |
| 26 | Long      | 90    | 21  | F      | 3          | 2      | 1         | None                       | 0.281  | 0.415                 |
| 27 | Long      | 91    | 18  | M      | 4          | 3      | 4         | None                       | -0.228 | -0.220                |
| 28 | Long      | 72    | 21  | F      | 5          | 2      | 3         | None                       | 0.190  | 0.190                 |
| 29 | Long      | 91    | 19  | F      | 3          | 5      | 2         | Think about something else | 0.623  | 0.845                 |
| 30 | Long      | 91    | 19  | M      | 3          | 6      | 4         | None                       | 0.325  | -0.242                |
| 31 | Long      | 72    | 18  | M      | 6          | 1      | 2         | None                       | -0.076 | -0.076                |
| 32 | Long      | 63    | 23  | F      | 3          | 2      | 6         | None                       | 0.427  | 0.427                 |
| 33 | Long      | 63    | 23  | F      | 4          | 1      | 2         | None                       | 0.161  | 0.000                 |
| 34 | Long      | 90    | 21  | F      | 5          | 1      | 3         | Think about something else | -0.077 | -0.030                |
| 35 | Long      | 79    | 19  | F      | 3          | 1      | 3         | None                       |        |                       |
| 36 | Long      | 66    | 22  | M      | 4          | 2      | 4         | None                       | 0.476  | -0.288                |
| 37 | Long      | 65    | 44  | F      | 4          | 2      | 4         | None                       | 0.457  | 0.548                 |
| 38 | Long      | 66    | 19  | F      | 5          | 1      | 5         | None                       |        |                       |
| 39 | Long      | 60    | 18  | F      | 6          | 1      | 1         | None                       | 0.300  | 0.419                 |
| 40 | Long      | 60    | 21  | M      | 4          | 4      | 2         | None                       | 0.123  | 0.507                 |
| 41 | Long      | 68    | 19  | F      | 3          | 2      | 1         | Slow Breathing             | -0.102 | -0.102                |
| 42 | Long      | 63    | 22  | F      | 5          | 1      | 3         | None                       | -0.073 | -0.073                |
| 43 | Long      | 66    | 20  | M      | 6          | 4      | 1         | None                       | -0.098 | 0.175                 |
| 44 | Short     | 2     | 23  | M      | 6          | 1      | 2         | None                       | 0.085  | 0.085                 |
| 45 | Short     | 2     | 22  | F      | 4          | 2      | 1         | None                       | 0.073  | 0.073                 |

Table A.14. Fading Memories, Experiment 2 Data

| P  | Condition | Age | Gender | Motivation | Stress | Innocence | Countermeasure             | Normalised Mean SCR |         | Normalised Mean HR |         |
|----|-----------|-----|--------|------------|--------|-----------|----------------------------|---------------------|---------|--------------------|---------|
|    |           |     |        |            |        |           |                            | Abrupt              | Gradual | Abrupt             | Gradual |
| 1  | Rapid1st  | 20  | F      | 6          | 4      | 3         | None                       | 0.302               | 0.902   | -0.624             | 0.755   |
| 2  | Fade1st   | 19  | F      | 6          | 4      | 2         | None                       | -0.011              | -0.391  | -0.117             | -0.376  |
| 3  | Rapid1st  | 18  | F      | 6          | 4      | 4         | Slow Breathing             | 0.413               | 0.697   | -0.082             | 0.032   |
| 4  | Fade1st   | 21  | M      | 6          | 5      | 1         | None                       | 0.090               | 0.309   | -0.249             | -0.339  |
| 5  | Rapid1st  | 19  | F      | 5          | 3      | 4         | None                       | 0.634               | 0.027   | 0.979              | 0.438   |
| 6  | Fade1st   | 20  | M      | 5          | 4      | 3         | None                       | 1.661               | 0.001   | -1.069             | -0.079  |
| 7  | Rapid1st  | 20  | F      | 6          | 5      | 4         | Calm                       |                     |         |                    |         |
| 8  | Rapid1st  | 20  | F      | 6          | 2      | 2         | None                       | 1.068               | -0.264  | -0.153             | -0.834  |
| 9  | Rapid1st  | 20  | M      | 5          | 2      | 5         | None                       | 1.395               | -0.345  |                    |         |
| 10 | Fade1st   | 19  | M      | 4          | 2      | 5         | Slow Heart Rate            | 1.079               | 0.137   |                    |         |
| 11 | Rapid1st  | 19  | M      | 5          | 4      | 3         | None                       | 0.373               | 0.897   | 0.292              | 0.365   |
| 12 | Fade1st   | 20  | F      | 5          | 4      | 4         | None                       | 1.159               | 0.579   | 0.271              | -1.276  |
| 13 | Rapid1st  | 29  | F      | 6          | 3      | 5         | None                       |                     |         | 0.278              | 0.332   |
| 14 | Fade1st   | 22  | F      | 5          | 4      | 5         | Calm                       | 0.398               | 0.841   | 0.250              | -0.759  |
| 15 | Rapid1st  | 24  | F      | 5          | 4      | 4         | Slow Breathing             | 0.365               | -0.930  | -1.054             | 0.443   |
| 16 | Fade1st   | 18  | F      | 5          | 5      | 3         | None                       | 0.158               | -0.736  | 0.653              | 0.074   |
| 17 | Rapid1st  | 19  | F      | 6          | 1      | 5         | Slow Breathing             | 1.142               | -0.018  | -0.165             | -0.417  |
| 18 | Fade1st   | 23  | F      | 5          | 3      | 4         | Slow Breathing             |                     |         | -0.513             | -0.132  |
| 19 | Rapid1st  | 19  | M      | 6          | 6      | 3         | None                       | 1.133               | -0.072  | -0.400             | 0.152   |
| 20 | Fade1st   | 19  | F      | 4          | 1      | 4         | None                       | 0.022               | 0.664   | -1.647             | 0.602   |
| 21 | Fade1st   | 23  | F      | 5          | 3      | 2         | None                       |                     |         | -0.574             | -0.241  |
| 22 | Rapid1st  | 19  | M      | 5          | 3      | 4         | None                       | 1.734               | -0.308  | 0.156              | -0.751  |
| 23 | Fade1st   | 21  | M      | 6          | 3      | 4         | None                       | 1.278               | 0.611   | -1.164             | 0.367   |
| 24 | Rapid1st  | 21  | M      | 5          | 2      | 4         | None                       | 1.610               | -0.273  | -0.710             | -1.072  |
| 25 | Fade1st   | 22  | F      | 4          | 2      | 3         | None                       | -0.086              | 1.050   | 0.618              | 0.401   |
| 26 | Rapid1st  | 36  | M      | 5          | 3      | 4         | None                       | 0.477               | 0.392   | -0.286             | -0.363  |
| 27 | Fade1st   | 22  | F      | 6          | 4      | 3         | None                       | 0.892               | 0.475   | -0.345             | 0.309   |
| 28 | Rapid1st  | 20  | M      | 5          | 4      | 2         | Think about something else | 0.992               | 1.640   | -0.670             | -0.275  |
| 29 | Fade1st   | 19  | F      | 5          | 3      | 4         | Think about something else | -0.319              | 0.146   | -0.627             | 0.606   |
| 30 | Rapid1st  | 19  | M      | 6          | 1      | 6         | None                       | 0.350               | 1.034   | 0.188              | -0.653  |
| 31 | Fade1st   | 21  | F      | 6          | 1      | 6         | None                       | 0.067               | 0.196   | -0.806             | -0.312  |
| 32 | Rapid1st  | 21  | F      | 6          | 5      | 2         | None                       | -0.244              | 1.030   | -0.678             | -0.185  |
| 33 | Fade1st   | 23  | M      | 4          | 2      | 4         | Attended to controls       | 1.219               | 0.797   | 0.672              | -1.119  |
| 34 | Rapid1st  | 20  | F      | 6          | 3      | 3         | Slow Breathing             | 1.506               | 0.002   | -0.403             | 0.588   |
| 35 | Fade1st   | 20  | F      | 6          | 4      | 3         | None                       | 1.450               | -0.193  | 0.144              | 0.303   |
| 36 | Rapid1st  | 20  | F      | 4          | 3      | 2         | Calm                       | 0.541               | 0.676   | 0.222              | 0.173   |
| 37 | Fade1st   | 21  | F      | 4          | 3      | 5         | None                       | -0.302              | -0.016  | -1.365             | -0.011  |
| 38 | Rapid1st  | 18  | F      | 5          | 3      | 3         | None                       | -0.037              | 0.146   | 0.703              | -0.316  |
| 39 | Fade1st   | 19  | F      | 4          | 2      | 4         | None                       | 1.396               | 0.657   | -0.498             | -0.840  |
| 40 | Rapid1st  | 19  | M      | 6          | 2      | 5         | Attended to controls       | 0.664               | 1.186   | 0.609              | -0.460  |

Table A.15. *Upstanding or Underhand, Experiment 1 Data*

| P  | Condition | Mean Reaction Times |       |         |       | Mean % Errors |       |         |       |
|----|-----------|---------------------|-------|---------|-------|---------------|-------|---------|-------|
|    |           | Bottom              |       | Top     |       | Bottom        |       | Top     |       |
|    |           | Control             | Crime | Control | Crime | Control       | Crime | Control | Crime |
| 1  | A         | 512                 | 534   | 525     | 541   | 0             | 3     | 1       | 2     |
| 2  | A         | 523                 | 531   | 518     | 522   | 0             | 0     | 1       | 0     |
| 3  | A         | 478                 | 519   | 478     | 537   | 0             | 0     | 1       | 0     |
| 4  | A         | 493                 | 515   | 503     | 496   | 3             | 3     | 1       | 5     |
| 5  | A         | 427                 | 391   | 461     | 460   | 1             | 5     | 1       | 0     |
| 6  | A         | 562                 | 523   | 547     | 591   | 15            | 26    | 14      | 10    |
| 7  | A         | 464                 | 441   | 464     | 456   | 8             | 6     | 1       | 2     |
| 8  | A         | 496                 | 512   | 504     | 504   | 1             | 3     | 2       | 7     |
| 9  | A         | 503                 | 478   | 516     | 521   | 3             | 3     | 5       | 2     |
| 10 | A         | 492                 | 477   | 469     | 470   | 3             | 0     | 3       | 0     |
| 11 | A         | 552                 | 589   | 524     | 584   | 0             | 3     | 0       | 0     |
| 12 | A         | 565                 | 601   | 573     | 624   | 0             | 3     | 0       | 0     |
| 13 | A         | 539                 | 550   | 553     | 562   | 1             | 0     | 0       | 5     |
| 14 | A         | 479                 | 541   | 480     | 488   | 1             | 6     | 2       | 0     |
| 15 | A         | 544                 | 553   | 593     | 598   | 1             | 0     | 0       | 0     |
| 16 | A         | 453                 | 494   | 451     | 490   | 1             | 0     | 1       | 6     |
| 17 | A         | 459                 | 470   | 474     | 484   | 0             | 3     | 0       | 0     |
| 18 | A         | 509                 | 543   | 494     | 543   | 4             | 11    | 1       | 8     |
| 19 | A         | 481                 | 496   | 464     | 478   | 2             | 0     | 3       | 0     |
| 20 | A         | 445                 | 429   | 459     | 430   | 1             | 3     | 1       | 0     |
| 21 | A         | 493                 | 489   | 501     | 493   | 1             | 0     | 1       | 3     |
| 22 | A         | 533                 | 522   | 533     | 528   | 4             | 2     | 4       | 0     |
| 23 | A         | 508                 | 570   | 470     | 517   | 0             | 3     | 0       | 0     |
| 24 | A         | 581                 | 598   | 598     | 564   | 0             | 3     | 0       | 7     |
| 25 | A         | 578                 | 620   | 586     | 593   | 0             | 7     | 0       | 2     |
| 26 | A         | 463                 | 526   | 459     | 535   | 0             | 0     | 0       | 5     |
| 27 | B         | 587                 | 586   | 545     | 573   | 1             | 0     | 1       | 0     |
| 28 | B         | 450                 | 438   | 474     | 450   | 1             | 5     | 3       | 0     |
| 29 | B         | 541                 | 533   | 528     | 551   | 0             | 0     | 0       | 0     |
| 30 | B         | 479                 | 460   | 469     | 499   | 0             | 3     | 0       | 0     |
| 31 | B         | 575                 | 619   | 561     | 590   | 29            | 24    | 17      | 11    |
| 32 | B         | 531                 | 526   | 488     | 490   | 1             | 3     | 0       | 0     |
| 33 | B         | 442                 | 428   | 465     | 474   | 0             | 3     | 0       | 3     |
| 34 | B         | 521                 | 534   | 544     | 559   | 7             | 0     | 5       | 0     |
| 35 | B         | 499                 | 501   | 497     | 497   | 6             | 0     | 9       | 6     |
| 36 | B         | 533                 | 514   | 548     | 567   | 5             | 14    | 5       | 21    |
| 37 | B         | 535                 | 549   | 544     | 590   | 0             | 3     | 0       | 3     |
| 38 | B         | 509                 | 522   | 541     | 553   | 4             | 3     | 10      | 5     |
| 39 | B         | 628                 | 658   | 623     | 655   | 11            | 17    | 15      | 5     |
| 40 | B         | 497                 | 530   | 510     | 538   | 0             | 0     | 1       | 0     |
| 41 | B         | 568                 | 575   | 550     | 549   | 19            | 0     | 16      | 8     |
| 42 | B         | 760                 | 629   | 618     | 632   | 92            | 21    | 91      | 5     |
| 43 | B         | 556                 | 566   | 533     | 597   | 0             | 5     | 0       | 5     |
| 44 | B         | 572                 | 577   | 571     | 614   | 13            | 8     | 12      | 20    |
| 45 | B         | 601                 | 610   | 588     | 619   | 1             | 0     | 3       | 0     |
| 46 | B         | 476                 | 488   | 494     | 524   | 0             | 0     | 1       | 0     |
| 47 | B         | 653                 | 612   | 644     | 635   | 61            | 10    | 54      | 11    |
| 48 | B         | 570                 | 621   | 594     | 640   | 4             | 3     | 2       | 0     |
| 49 | B         | 492                 | 497   | 502     | 494   | 1             | 0     | 3       | 3     |
| 50 | B         | 537                 | 561   | 523     | 563   | 0             | 0     | 0       | 0     |
| 51 | B         | 513                 | 518   | 502     | 512   | 0             | 0     | 0       | 0     |
| 52 | B         | 571                 | 567   | 570     | 562   | 1             | 0     | 1       | 0     |
| 53 | C         | 507                 | 526   | 489     | 499   | 0             | 0     | 1       | 0     |
| 54 | C         | 572                 | 587   | 536     | 585   | 5             | 0     | 2       | 2     |
| 55 | C         | 514                 | 529   | 490     | 506   | 1             | 3     | 1       | 2     |

|    |   |     |     |     |     |    |    |    |    |
|----|---|-----|-----|-----|-----|----|----|----|----|
| 56 | C | 535 | 537 | 528 | 529 | 1  | 0  | 1  | 0  |
| 57 | C | 505 | 488 | 491 | 513 | 11 | 10 | 10 | 4  |
| 58 | C | 603 | 580 | 598 | 572 | 2  | 9  | 1  | 0  |
| 59 | C | 567 | 533 | 547 | 580 | 2  | 6  | 9  | 0  |
| 60 | C | 498 | 516 | 504 | 503 | 1  | 5  | 1  | 0  |
| 61 | C | 553 | 582 | 560 | 522 | 6  | 5  | 6  | 13 |
| 62 | C | 510 | 526 | 512 | 539 | 1  | 0  | 0  | 0  |
| 63 | C | 477 | 476 | 463 | 504 | 0  | 0  | 0  | 0  |
| 64 | C | 493 | 574 | 521 | 526 | 1  | 3  | 0  | 3  |
| 65 | C | 520 | 512 | 525 | 553 | 0  | 6  | 0  | 0  |
| 66 | C | 557 | 583 | 539 | 573 | 11 | 0  | 16 | 0  |
| 67 | C | 501 | 512 | 515 | 565 | 1  | 0  | 1  | 6  |
| 68 | C | 468 | 497 | 467 | 538 | 1  | 6  | 0  | 0  |
| 69 | C | 439 | 452 | 470 | 471 | 0  | 0  | 0  | 3  |
| 70 | C | 471 | 498 | 472 | 510 | 1  | 2  | 0  | 3  |
| 71 | C | 536 | 558 | 547 | 597 | 2  | 6  | 5  | 3  |
| 72 | C | 530 | 583 | 539 | 555 | 1  | 9  | 1  | 0  |
| 73 | C | 637 | 644 | 629 | 659 | 1  | 0  | 2  | 0  |
| 74 | C | 561 | 614 | 570 | 590 | 4  | 7  | 6  | 7  |
| 75 | C | 529 | 519 | 492 | 520 | 1  | 0  | 0  | 0  |
| 76 | C | 492 | 466 | 496 | 529 | 0  | 3  | 0  | 2  |

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Table A.16. *Upstanding or Underhand, Experiment 2 Data*

| P  | Mean Reaction Times |       |         |       | Mean % Errors |       |         |       |
|----|---------------------|-------|---------|-------|---------------|-------|---------|-------|
|    | Bottom              |       | Top     |       | Bottom        |       | Top     |       |
|    | Control             | Crime | Control | Crime | Control       | Crime | Control | Crime |
| 1  | 424                 | 438   | 423     | 478   | 1             | 3     | 0       | 0     |
| 2  | 548                 | 535   | 533     | 547   | 1             | 0     | 1       | 0     |
| 3  | 633                 | 706   | 641     | 726   | 18            | 13    | 16      | 10    |
| 4  | 494                 | 496   | 489     | 536   | 1             | 0     | 0       | 0     |
| 5  | 485                 | 473   | 475     | 536   | 1             | 3     | 0       | 0     |
| 6  | 454                 | 476   | 446     | 468   | 1             | 3     | 1       | 6     |
| 7  | 565                 | 590   | 567     | 579   | 7             | 8     | 5       | 6     |
| 8  | 500                 | 502   | 464     | 530   | 1             | 0     | 0       | 0     |
| 9  | 472                 | 507   | 491     | 515   | 1             | 3     | 1       | 0     |
| 10 | 442                 | 438   | 425     | 451   | 1             | 0     | 0       | 0     |
| 11 | 506                 | 515   | 530     | 538   | 0             | 0     | 1       | 0     |
| 12 | 477                 | 496   | 481     | 564   | 0             | 0     | 0       | 6     |
| 13 | 585                 | 609   | 573     | 626   | 0             | 0     | 0       | 0     |
| 14 | 579                 | 577   | 540     | 586   | 9             | 6     | 7       | 10    |
| 15 | 578                 | 572   | 563     | 595   | 1             | 0     | 1       | 5     |
| 16 | 576                 | 586   | 549     | 553   | 0             | 0     | 0       | 0     |
| 17 | 443                 | 425   | 473     | 490   | 1             | 0     | 0       | 0     |
| 18 | 531                 | 527   | 511     | 560   | 0             | 0     | 0       | 0     |
| 19 | 506                 | 569   | 498     | 548   | 0             | 8     | 0       | 3     |
| 20 | 410                 | 395   | 383     | 392   | 26            | 23    | 25      | 21    |
| 21 | 651                 | 692   | 636     | 660   | 18            | 5     | 15      | 0     |
| 22 | 561                 | 580   | 542     | 605   | 1             | 0     | 1       | 3     |
| 23 | 519                 | 558   | 520     | 588   | 0             | 0     | 0       | 0     |
| 24 | 650                 | 694   | 645     | 696   | 0             | 0     | 0       | 0     |
| 25 | 496                 | 565   | 497     | 548   | 1             | 8     | 1       | 3     |
| 26 | 509                 | 496   | 469     | 554   | 1             | 0     | 0       | 3     |
| 27 | 508                 | 581   | 536     | 603   | 0             | 0     | 0       | 3     |



Table A.17. *Upstanding or Underhand, Experiment 3 Data*

| P  | Suspect | Mean Reaction Times |       |         |       | Mean % Errors |       |         |       |
|----|---------|---------------------|-------|---------|-------|---------------|-------|---------|-------|
|    |         | Bottom              |       | Top     |       | Bottom        |       | Top     |       |
|    |         | Control             | Crime | Control | Crime | Control       | Crime | Control | Crime |
| 1  | G       | 491                 | 491   | 511     | 532   | 1             | 0     | 0       | 4     |
| 2  | G       | 522                 | 612   | 513     | 597   | 0             | 0     | 0       | 0     |
| 3  | G       | 451                 | 483   | 464     | 485   | 1             | 0     | 1       | 0     |
| 4  | G       | 430                 | 420   | 413     | 429   | 0             | 0     | 1       | 0     |
| 5  | G       | 462                 | 508   | 482     | 519   | 0             | 0     | 0       | 0     |
| 6  | G       | 530                 | 505   | 558     | 546   | 17            | 26    | 31      | 24    |
| 7  | G       | 497                 | 514   | 513     | 537   | 0             | 0     | 1       | 3     |
| 8  | G       | 559                 | 567   | 568     | 584   | 0             | 0     | 0       | 0     |
| 9  | G       | 446                 | 461   | 447     | 458   | 0             | 0     | 0       | 0     |
| 10 | G       | 499                 | 489   | 463     | 426   | 2             | 0     | 1       | 5     |
| 11 | G       | 463                 | 486   | 482     | 489   | 1             | 3     | 0       | 0     |
| 12 | G       | 462                 | 493   | 430     | 487   | 0             | 0     | 0       | 0     |
| 13 | G       | 502                 | 489   | 514     | 519   | 0             | 0     | 0       | 0     |
| 14 | G       | 540                 | 550   | 564     | 580   | 5             | 7     | 4       | 0     |
| 15 | G       | 426                 | 433   | 433     | 428   | 0             | 0     | 0       | 0     |
| 16 | G       | 415                 | 436   | 439     | 446   | 1             | 0     | 3       | 0     |
| 17 | G       | 502                 | 481   | 481     | 487   | 0             | 0     | 1       | 0     |
| 18 | G       | 519                 | 556   | 522     | 531   | 0             | 5     | 0       | 0     |
| 19 | G       | 448                 | 438   | 452     | 431   | 2             | 0     | 2       | 0     |
| 20 | G       | 502                 | 531   | 495     | 532   | 0             | 0     | 0       | 4     |
| 21 | G       | 512                 | 502   | 515     | 538   | 1             | 3     | 0       | 8     |
| 22 | G       | 513                 | 531   | 526     | 581   | 1             | 0     | 1       | 4     |
| 23 | G       | 500                 | 522   | 511     | 527   | 0             | 0     | 0       | 0     |
| 24 | G       | 482                 | 485   | 461     | 519   | 0             | 0     | 0       | 0     |
| 25 | G       | 499                 | 494   | 520     | 520   | 0             | 0     | 0       | 0     |
| 26 | G       | 499                 | 569   | 516     | 579   | 0             | 0     | 0       | 0     |
| 27 | G       | 423                 | 440   | 425     | 433   | 1             | 4     | 3       | 0     |
| 28 | G       |                     |       |         |       |               |       |         |       |
| 29 | G       | 485                 | 455   | 501     | 503   | 1             | 0     | 1       | 0     |
| 30 | G       | 544                 | 531   | 548     | 565   | 0             | 0     | 0       | 0     |
| 31 | G       | 514                 | 518   | 507     | 610   | 0             | 0     | 1       | 0     |
| 32 | G       | 511                 | 568   | 517     | 536   | 0             | 0     | 2       | 0     |
| 33 | G       | 521                 | 560   | 525     | 621   | 0             | 7     | 0       | 0     |
| 34 | G       |                     |       |         |       |               |       |         |       |
| 35 | G       | 465                 | 456   | 479     | 460   | 0             | 4     | 1       | 0     |
| 36 | G       | 532                 | 541   | 527     | 616   | 0             | 4     | 1       | 0     |
| 37 | G       | 445                 | 464   | 451     | 510   | 0             | 0     | 0       | 0     |
| 38 | G       | 501                 | 543   | 477     | 546   | 1             | 0     | 0       | 0     |
| 39 | G       | 512                 | 591   | 542     | 588   | 0             | 0     | 0       | 0     |
| 40 | G       | 550                 | 512   | 529     | 552   | 0             | 0     | 0       | 0     |
| 41 | G       | 428                 | 417   | 426     | 478   | 10            | 0     | 1       | 8     |
| 42 | G       | 510                 | 496   | 507     | 537   | 0             | 0     | 0       | 0     |
| 43 | G       | 433                 | 449   | 447     | 456   | 0             | 0     | 0       | 0     |
| 44 | G       | 507                 | 512   | 514     | 521   | 0             | 0     | 0       | 0     |
| 45 | G       | 553                 | 564   | 570     | 609   | 1             | 0     | 0       | 0     |
| 46 | I       | 547                 | 527   | 509     | 484   | 0             | 0     | 0       | 0     |
| 47 | I       | 525                 | 537   | 502     | 497   | 1             | 0     | 0       | 0     |
| 48 | I       | 567                 | 540   | 583     | 528   | 6             | 3     | 7       | 0     |
| 49 | I       | 473                 | 483   | 464     | 470   | 0             | 0     | 0       | 0     |
| 50 | I       | 518                 | 527   | 520     | 495   | 2             | 0     | 3       | 6     |
| 51 | I       | 544                 | 555   | 552     | 556   | 0             | 3     | 1       | 0     |
| 52 | I       | 512                 | 479   | 527     | 514   | 1             | 0     | 0       | 0     |
| 53 | I       | 473                 | 447   | 489     | 478   | 0             | 0     | 0       | 0     |
| 54 | I       | 421                 | 404   | 412     | 418   | 1             | 3     | 1       | 0     |

|    |   |     |     |     |     |   |   |   |   |
|----|---|-----|-----|-----|-----|---|---|---|---|
| 55 | I | 478 | 472 | 472 | 453 | 1 | 0 | 4 | 0 |
| 56 | I | 513 | 505 | 497 | 475 | 0 | 0 | 1 | 0 |
| 57 | I | 480 | 459 | 465 | 442 | 0 | 0 | 1 | 0 |
| 58 | I | 598 | 610 | 591 | 613 | 1 | 0 | 1 | 0 |
| 59 | I | 526 | 514 | 509 | 497 | 1 | 0 | 1 | 0 |
| 60 | I | 537 | 525 | 536 | 538 | 0 | 0 | 0 | 0 |
| 61 | I | 493 | 468 | 436 | 409 | 2 | 0 | 1 | 0 |
| 62 | I | 550 | 514 | 546 | 523 | 0 | 0 | 1 | 0 |
| 63 | I | 449 | 457 | 439 | 412 | 1 | 0 | 1 | 0 |
| 64 | I | 534 | 518 | 526 | 516 | 0 | 0 | 1 | 3 |
| 65 | I | 456 | 425 | 459 | 417 | 0 | 0 | 1 | 0 |
| 66 | I | 516 | 482 | 493 | 470 | 0 | 0 | 1 | 0 |
| 67 | I | 544 | 553 | 538 | 537 | 0 | 0 | 0 | 0 |
| 68 | I | 549 | 531 | 553 | 536 | 0 | 0 | 0 | 0 |
| 69 | I | 463 | 446 | 435 | 435 | 0 | 0 | 1 | 0 |
| 70 | I | 506 | 521 | 486 | 476 | 0 | 0 | 1 | 0 |
| 71 | I | 481 | 460 | 495 | 505 | 2 | 3 | 0 | 0 |
| 72 | I | 496 | 477 | 475 | 460 | 0 | 0 | 0 | 0 |
| 73 | I | 554 | 539 | 544 | 545 | 1 | 3 | 2 | 0 |
| 74 | I | 544 | 525 | 539 | 515 | 1 | 3 | 1 | 0 |
| 75 | I | 498 | 506 | 478 | 477 | 0 | 0 | 0 | 0 |
| 76 | I | 528 | 524 | 502 | 479 | 1 | 0 | 1 | 0 |
| 77 | I | 496 | 471 | 488 | 495 | 0 | 0 | 0 | 0 |
| 78 | I | 503 | 499 | 488 | 467 | 0 | 0 | 0 | 0 |
| 79 | I | 553 | 577 | 566 | 578 | 0 | 0 | 0 | 0 |
| 80 | I | 525 | 563 | 525 | 535 | 1 | 3 | 0 | 0 |
| 81 | I | 541 | 536 | 506 | 486 | 0 | 0 | 1 | 0 |
| 82 | I | 493 | 494 | 476 | 448 | 1 | 0 | 0 | 0 |
| 83 | I | 480 | 488 | 488 | 484 | 1 | 3 | 5 | 3 |
| 84 | I | 423 | 420 | 414 | 405 | 1 | 3 | 1 | 0 |
| 85 | I | 481 | 491 | 477 | 449 | 1 | 0 | 0 | 0 |
| 86 | I | 497 | 474 | 492 | 473 | 0 | 0 | 0 | 0 |
| 87 | I | 486 | 502 | 498 | 490 | 0 | 0 | 0 | 0 |

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Table A.18. Fading Memories, Experiment 2(pilot) Data

| P  | Age | Gender | Motivation | Innocence | Countermeasures            | Mean Normalised SCR |        | Mean Normalised HR |        |
|----|-----|--------|------------|-----------|----------------------------|---------------------|--------|--------------------|--------|
|    |     |        |            |           |                            | Control             | Crime  | Control            | Crime  |
| 1  | 20  | M      | 6          | 6         | None                       | -0.054              | 0.162  | 0.058              | -0.174 |
| 2  | 20  | F      | 3          | 5         | None                       | -0.099              | 0.298  | 0.000              | 0.001  |
| 3  | 20  | M      | 5          | 4         | None                       | -0.101              | 0.303  | 0.059              | -0.177 |
| 4  | 20  | F      | 5          | 3         | None                       | 0.057               | -0.171 | -0.119             | 0.358  |
| 5  | 20  | M      | 6          | 1         | None                       | -0.133              | 0.398  | 0.064              | -0.192 |
| 6  | 20  | F      | 6          | 6         | Slow Breathing             | 0.014               | -0.043 | 0.155              | -0.464 |
| 7  | 20  | F      | 4          | 3         | None                       |                     |        | 0.023              | -0.068 |
| 8  | 21  | F      | 4          | 3         | None                       | -0.129              | 0.388  | -0.157             | 0.472  |
| 9  | 19  | M      | 4          | 5         | Covert Movement            | 0.090               | -0.270 | 0.121              | -0.364 |
| 10 | 23  | F      | 5          | 3         | Calm                       | 0.062               | -0.186 | -0.095             | 0.286  |
| 11 | 19  | F      | 4          | 2         | None                       | -0.200              | 0.601  | 0.129              | -0.387 |
| 12 | 20  | F      | 6          | 5         | Slow Breathing             | -0.018              | 0.054  | 0.063              | -0.188 |
| 13 | 20  | F      | 6          | 4         | None                       | -0.076              | 0.227  | 0.164              | -0.492 |
| 14 | 20  | M      | 6          | 4         | None                       | -0.352              | 1.057  | 0.124              | -0.371 |
| 15 | 21  | F      | 4          | 2         | Slow Breathing             | -0.014              | 0.043  | 0.093              | -0.279 |
| 16 | 20  | F      | 6          | 4         | Slow Breathing             | -0.033              | 0.100  | 0.101              | -0.304 |
| 17 | 19  | F      | 4          | 2         | None                       | -0.030              | 0.089  | -0.135             | 0.405  |
| 18 | 21  | F      | 6          | 4         | None                       | -0.151              | 0.452  | 0.099              | -0.296 |
| 19 | 21  | F      | 5          | 4         | None                       | -0.112              | 0.336  | -0.074             | 0.221  |
| 20 | 20  | M      | 6          | 5         | Think about something else | 0.074               | -0.221 | 0.036              | -0.109 |
| 21 | 21  | F      | 4          | 6         | None                       | 0.050               | -0.150 | 0.050              | -0.151 |
| 22 | 22  | F      | 3          | 3         | Think about something else | 0.043               | -0.130 | 0.103              | -0.310 |
| 23 | 20  | F      | 6          | 6         | None                       |                     |        | 0.161              | -0.482 |
| 24 | 20  | F      | 5          | 5         | None                       | -0.009              | 0.026  | -0.017             | 0.052  |
| 25 | 19  | M      | 3          | 5         | Slow Breathing             | 0.020               | -0.061 | -0.119             | 0.358  |
| 26 | 20  | F      | 5          | 4         | None                       | 0.070               | -0.210 | 0.180              | -0.541 |
| 27 | 20  | F      | 5          | 4         | None                       | -0.121              | 0.364  | 0.117              | -0.350 |
| 28 | 18  | F      | 5          | 4         | None                       | -0.036              | 0.109  | 0.186              | -0.558 |
| 29 | 20  | F      | 4          | 4         | None                       |                     |        | 0.131              | -0.394 |
| 30 | 21  | M      | 6          | 3         | Think about something else | -0.077              | 0.231  | -0.055             | 0.166  |
| 31 | 21  | M      | 6          | 5         | None                       |                     |        | 0.065              | -0.195 |
| 32 | 21  | F      | 5          | 2         | Think about something else |                     |        | 0.083              | -0.250 |
| 33 | 20  | M      | 5          | 4         | None                       | -0.155              | 0.452  | -0.069             | 0.200  |
| 34 | 21  | F      | 6          | 4         | None                       | -0.098              | 0.295  | 0.085              | -0.256 |
| 35 | 20  | F      | 6          | 2         | Slow Breathing             | -0.007              | 0.021  | -0.118             | 0.354  |
| 36 | 21  | M      | 5          | 2         | None                       |                     |        | 0.110              | -0.329 |
| 37 | 19  | M      | 5          | 2         | Slow Breathing             | -0.057              | 0.170  | 0.128              | -0.383 |
| 38 | 20  | M      | 5          | 4         | Slow Heart Rate            | -0.118              | 0.355  | 0.037              | -0.112 |
| 39 | 22  | F      | 3          | 3         | None                       | -0.124              | 0.373  | 0.076              | -0.228 |
| 40 | 21  | F      | 6          | 3         | None                       | 0.080               | -0.240 | 0.060              | -0.179 |
| 41 | 21  | M      | 5          | 4         | None                       |                     |        | 0.029              | -0.086 |
| 42 | 20  | F      | 5          | 4         | None                       | -0.155              | 0.466  | 0.076              | -0.228 |
| 43 | 21  | F      | 6          | 5         | Think about something else | -0.011              | 0.033  | -0.110             | 0.330  |

Table A.19. Scene Stimuli Physiology CIT Data

| P   | Age | Gender | Motivation | Stress | Innocence | Countermeasures            | Mean Normalised SCR |        | Mean Normalised HR |        |
|-----|-----|--------|------------|--------|-----------|----------------------------|---------------------|--------|--------------------|--------|
|     |     |        |            |        |           |                            | Control             | Crime  | Control            | Crime  |
| 1A  | 18  | F      | 5          | 2      | 3         | None                       | -0.316              | 0.947  | 0.167              | -0.502 |
| 2A  | 19  | M      | 6          | 3      | 4         | None                       | -0.382              | 1.146  | 0.235              | -0.704 |
| 3A  | 18  | F      | 2          | 1      | 2         | None                       | -0.017              | 0.050  | 0.108              | -0.324 |
| 4A  | 18  | F      | 5          | 4      | 5         | None                       | -0.014              | 0.041  | 0.115              | -0.345 |
| 5A  | 19  | F      | 3          | 1      | 2         | None                       | -0.298              | 0.895  | 0.008              | -0.024 |
| 6A  | 20  | M      | 2          | 3      | 3         | None                       | -0.296              | 0.889  | -0.220             | 0.659  |
| 7A  | 21  | M      | 5          | 5      | 4         | Suppressing Memory         | -0.065              | 0.196  | 0.189              | -0.567 |
| 8A  | 22  | M      | 3          | 1      | 2         | None                       |                     |        | -0.189             | 0.568  |
| 9A  | 22  | F      | 6          | 2      | 3         | Slow Breathing             | -0.171              | 0.514  | -0.115             | 0.345  |
| 10A | 34  | M      | 6          | 3      | 4         | Attend to Controls         | -0.323              | 0.970  | 0.091              | -0.273 |
| 11A | 22  | F      | 4          | 1      | 6         | Slow Breathing             | -0.022              | 0.067  | 0.150              | -0.451 |
| 12A | 18  | M      | 5          | 2      | 1         | None                       | -0.238              | 0.715  | 0.348              | -1.043 |
| 14A | 19  | M      | 4          | 3      | 2         | None                       | -0.163              | 0.488  | 0.166              | -0.498 |
| 15A | 22  | F      | 5          | 3      | 3         | None                       | -0.176              | 0.529  | 0.017              | -0.050 |
| 16A | 18  | F      | 3          | 1      | 4         | None                       | -0.349              | 1.048  | 0.125              | -0.375 |
| 17A | 18  | M      | 4          | 2      | 6         | None                       | -0.294              | 0.883  | -0.058             | 0.173  |
| 18A | 19  | F      | 6          | 3      | 3         | Attend to Controls         | -0.166              | 0.499  | -0.053             | 0.159  |
| 19A | 20  | F      | 2          | 2      | 2         | Slow Heart Rate            | -0.031              | 0.092  | 0.106              | -0.319 |
| 20A | 25  | M      | 4          | 4      | 4         | None                       | -0.426              | 1.278  | -0.048             | 0.143  |
| 1B  | 20  | M      | 3          | 2      | 1         | None                       | -0.504              | 0.180  | 0.250              | -0.728 |
| 2B  | 20  | M      | 4          | 3      | 2         | Slow Breathing             | -0.145              | 0.078  | -0.014             | -0.341 |
| 3B  | 21  | F      | 5          | 1      | 2         | Slow Breathing             | -0.200              | -0.200 | -0.177             | 0.170  |
| 5B  | 18  | F      | 3          | 4      | 4         | None                       | -0.233              | 0.497  | 0.092              | -0.824 |
| 6B  | 19  | F      | 4          | 2      | 2         | Think about something else | -0.250              | 0.399  | 0.335              | -0.618 |
| 7B  | 20  | M      | 3          | 3      | 2         | None                       | -0.320              | 0.626  | 0.275              | -1.039 |
| 8B  | 21  | F      | 3          | 3      | 3         | Slow Breathing             | -0.079              | 0.621  | 0.083              | -0.474 |
| 9B  | 20  | F      | 6          | 2      | 3         | Think about something else | -0.511              | -0.132 | 0.193              | -0.889 |
| 10B | 19  | F      | 4          | 1      | 5         | None                       | -0.312              | 0.378  | 0.282              | -0.589 |
| 11B | 19  | M      | 5          | 4      | 5         | Slow Breathing             | -0.338              | 0.393  | 0.002              | 0.501  |
| 12B | 22  | M      | 3          | 4      | 3         | None                       | -0.015              | 0.147  | 0.113              | -0.365 |
| 13B | 20  | F      | 4          | 3      | 5         | Slow Breathing             | -0.356              | -0.205 | 0.253              | -0.583 |
| 14B | 20  | M      | 5          | 4      | 4         | None                       | -0.458              | 0.236  | 0.118              | -0.464 |
| 15B | 20  | F      | 3          | 1      | 5         | Slow Breathing             | -0.289              | 0.141  | 0.194              | 0.211  |
| 16B | 22  | M      | 6          | 2      | 3         | Slow Breathing             | -0.456              | 0.048  | 0.033              | -0.516 |
| 17B | 23  | M      | 3          | 3      | 2         | Slow Breathing             | -0.422              | 0.634  | 0.045              | -0.061 |
| 18B | 20  | F      | 4          | 2      | 4         | None                       | -0.394              | 0.894  | 0.018              | 0.273  |
| 19B | 19  | F      | 5          | 1      | 2         | None                       | -0.200              | -0.200 | 0.297              | -0.714 |
| 20B | 22  | F      | 3          | 2      | 3         | Think about something else | -0.409              | 0.715  | -0.016             | -0.462 |
| 21B | 19  | F      | 5          | 2      | 5         | Slow Breathing             | -0.462              | 0.355  | -0.059             | -0.414 |
| 22B | 23  | F      | 2          | 2      | 5         | Think about something else | -0.179              | 0.036  | -0.085             | -0.259 |

Table A.20. Unobtrusive Measures Data

| P  | Suspect | Age | Gender | Motivation | Stress | Innocence | Countermeasures            | Mean Normalised<br>SCR |        | Mean Normalised<br>HR |        |
|----|---------|-----|--------|------------|--------|-----------|----------------------------|------------------------|--------|-----------------------|--------|
|    |         |     |        |            |        |           |                            | Control                | Crime  | Control               | Crime  |
| 1  | I       | 20  | M      | 4          | 3      | 2         | Breathing                  | -0.171                 | 0.368  | 0.084                 | -0.066 |
| 2  | G       | 21  | F      | 5          | 1      | 2         | Breathing                  | 0.100                  | -0.156 | 0.033                 | -0.399 |
| 3  | G       | 18  | F      | 2          | 3      | 6         | Think about something else | -0.183                 | 0.176  | -0.077                | 0.510  |
| 4  | G       | 18  | F      | 3          | 4      | 4         | None                       | -0.601                 | 0.990  | 0.124                 | -0.802 |
| 5  | G       | 19  | F      | 4          | 2      | 2         | Think about something else | -0.265                 | 0.150  | -0.010                | 0.094  |
| 6  | G       | 20  | M      | 3          | 3      | 2         | None                       | -0.287                 | 0.530  | 0.269                 | -0.229 |
| 7  | G       | 21  | F      | 3          | 3      | 3         | Breathing                  |                        |        | -0.252                | 0.522  |
| 8  | G       | 20  | F      | 6          | 2      | 3         | Think about something else | -0.079                 | 0.112  | -0.135                | 0.062  |
| 9  | I       | 19  | F      | 4          | 1      | 5         | None                       | -0.290                 | 0.102  | -0.146                | 0.093  |
| 10 | I       | 19  | M      | 5          | 4      | 5         | Breathing                  |                        |        | 0.008                 | -0.173 |
| 11 | I       | 22  | M      | 3          | 4      | 3         | None                       | -0.267                 | -0.140 | -0.005                | 0.163  |
| 12 | I       | 20  | F      | 4          | 3      | 5         | Breathing                  | -0.208                 | 0.087  | -0.023                | 0.000  |
| 13 | G       | 20  | M      | 5          | 4      | 4         | None                       | -0.009                 | 0.302  | 0.237                 | 0.035  |
| 14 | I       | 20  | F      | 3          | 1      | 5         | Breathing                  | -0.110                 | -0.114 | -0.215                | 0.812  |
| 15 | G       | 22  | M      | 6          | 2      | 3         | Breathing                  | -0.231                 | 0.403  | -0.147                | 0.115  |
| 16 | G       | 23  | M      | 3          | 3      | 2         | Breathing                  | -0.187                 | 0.739  | 0.356                 | -0.644 |
| 17 | G       | 20  | F      | 4          | 2      | 4         | None                       | -0.068                 | -0.165 | 0.218                 | -0.894 |
| 18 | I       | 19  | F      | 5          | 1      | 2         | None                       | -0.222                 | -0.251 | -0.035                | 0.111  |
| 19 | I       | 22  | F      | 3          | 2      | 3         | Think about something else | -0.220                 | -0.262 | -0.196                | 0.253  |
| 20 | I       | 19  | F      | 5          | 2      | 5         | Breathing                  | 0.120                  | -0.232 | -0.075                | 0.502  |
| 21 | I       | 23  | F      | 2          | 2      | 5         | Think about something else |                        |        | 0.007                 | -0.286 |

### Example Data

Table A.21. Example RTCIT Raw Data (from Upstanding or Underhand, Experiment 1)

| P  | IV<br>(WS) | Item<br>Type<br>(WS) | Epoch | CIT<br>Question | Trial<br>No. | Item    | Item String  | RTs | RT<br><200ms | Correct | Too<br>Slow |
|----|------------|----------------------|-------|-----------------|--------------|---------|--------------|-----|--------------|---------|-------------|
| 11 | A          | Bottom               | 1     | 3               | 1            | Control | 3.4.Control  | 564 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 20              | 2            | Crime   | 20.0.Crime   | 476 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 5               | 3            | Target  | 5.0.Target   | 800 | 0            | 2       | 0           |
| 11 | A          | Top                  | 1     | 14              | 4            | Control | 14.4.Control | 589 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 9               | 5            | Control | 9.2.Control  | 516 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 3               | 6            | Control | 3.2.Control  | 511 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 4               | 7            | Target  | 4.0.Target   | 578 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 16              | 8            | Control | 16.4.Control | 578 | 0            | 1       | 0           |
| 11 | A          | Top                  | 1     | 16              | 9            | Crime   | 16.0.Crime   | 470 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 20              | 10           | Control | 20.3.Control | 388 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 9               | 11           | Control | 9.3.Control  | 431 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 3               | 12           | Target  | 3.0.Target   | 536 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 1               | 13           | Target  | 1.0.Target   | 672 | 0            | 1       | 0           |
| 11 | A          | Top                  | 1     | 9               | 14           | Control | 9.4.Control  | 548 | 0            | 1       | 0           |
| 11 | A          | Top                  | 1     | 3               | 15           | Control | 3.3.Control  | 529 | 0            | 1       | 0           |
| 11 | A          | Top                  | 1     | 9               | 16           | Crime   | 9.0.Crime    | 738 | 0            | 1       | 0           |
| 11 | A          | Top                  | 1     | 3               | 17           | Control | 3.1.Control  | 456 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 14              | 18           | Control | 14.1.Control | 623 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 3               | 19           | Crime   | 3.0.Crime    | 472 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 20              | 20           | Control | 20.2.Control | 538 | 0            | 1       | 0           |
| 11 | A          | Top                  | 1     | 16              | 21           | Control | 16.3.Control | 369 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 20              | 22           | Control | 20.1.Control | 417 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 9               | 23           | Control | 9.1.Control  | 500 | 0            | 1       | 0           |
| 11 | A          | Top                  | 1     | 20              | 24           | Control | 20.4.Control | 375 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 16              | 25           | Control | 16.2.Control | 568 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 14              | 26           | Crime   | 14.0.Crime   | 676 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 14              | 27           | Control | 14.2.Control | 441 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 2               | 28           | Target  | 2.0.Target   | 588 | 0            | 1       | 0           |
| 11 | A          | Top                  | 1     | 16              | 29           | Control | 16.1.Control | 652 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 1     | 14              | 30           | Control | 14.3.Control | 528 | 0            | 1       | 0           |
| 11 | A          | Top                  | 2     | 14              | 31           | Control | 14.2.Control | 611 | 0            | 1       | 0           |
| 11 | A          | Bottom               | 2     | 16              | 32           | Control | 16.3.Control | 453 | 0            | 1       | 0           |
| 11 | A          | Top                  | 2     | 20              | 33           | Control | 20.4.Control | 388 | 0            | 1       | 0           |
| 11 | A          | Top                  | 2     | 20              | 34           | Crime   | 20.0.Crime   | 626 | 0            | 1       | 0           |

Table A.22. Example Physiology CIT Raw Data (from Partners in Crime, Experiment 1, P33)

| P Condition  | Item Type | CIT No | CIT Q | CIT Pos | Trial No. | Buffer | Item    | Item String | Description        | Trial Time | Raw SCR | Raw HR | Movement      |
|--------------|-----------|--------|-------|---------|-----------|--------|---------|-------------|--------------------|------------|---------|--------|---------------|
| 33 Suspect B | Objects   | 1      | 5     | 1       | 1         | 1      | Control | 5.1.Control | Earth              | 3          | 0.212   | 23.97  |               |
| 33 Suspect B | Objects   | 1      | 5     | 2       | 2         | 0      | Crime   | 5.0.Crime   | Brain              | 18         | 0.027   | -3.56  |               |
| 33 Suspect B | Objects   | 1      | 5     | 3       | 3         | 0      | Control | 5.4.Control | Heart              | 33         | 0.240   | 6.37   |               |
| 33 Suspect B | Objects   | 1      | 5     | 4       | 4         | 0      | Control | 5.2.Control | Clock              | 48         | 0.000   | -3.90  |               |
| 33 Suspect B | Objects   | 1      | 5     | 5       | 5         | 0      | Control | 5.3.Control | Jellyfish          | 63         | 0.326   | 3.51   |               |
| 33 Suspect B | Objects   | 2      | 7     | 1       | 6         | 1      | Control | 7.3.Control | Financial Details  | 91         | 0.052   | -1.07  |               |
| 33 Suspect B | Objects   | 2      | 7     | 2       | 7         | 0      | Crime   | 7.0.Crime   | Blueprints         | 106        | 0.243   | -1.88  |               |
| 33 Suspect B | Objects   | 2      | 7     | 3       | 8         | 0      | Control | 7.1.Control | Facility Locations | 121        | 0.084   | 3.73   |               |
| 33 Suspect B | Objects   | 2      | 7     | 4       | 9         | 0      | Control | 7.4.Control | Future Patents     | 136        | 0.056   | -15.39 |               |
| 33 Suspect B | Objects   | 2      | 7     | 5       | 10        | 0      | Control | 7.2.Control | Bespoke Software   | 151        | 0.222   | -0.04  |               |
| 33 Suspect A | Scene     | 3      | 4     | 1       | 11        | 1      | Control | 4.1.Control | Rail Station       | 179        | 0.287   | 1.00   |               |
| 33 Suspect A | Scene     | 3      | 4     | 2       | 12        | 0      | Control | 4.3.Control | Overpass           | 194        | 0.000   | 5.57   |               |
| 33 Suspect A | Scene     | 3      | 4     | 3       | 13        | 0      | Control | 4.4.Control | Town Centre        | 209        | 0.118   | 7.43   |               |
| 33 Suspect A | Scene     | 3      | 4     | 4       | 14        | 0      | Crime   | 4.0.Crime   | Cark Park          | 224        | 0.163   | -8.65  |               |
| 33 Suspect A | Scene     | 3      | 4     | 5       | 15        | 0      | Control | 4.2.Control | Park               | 239        | 0.000   | 5.87   |               |
| 33 Shared    | Objects   | 4      | 9     | 1       | 16        | 1      | Control | 9.3.Control | Sledgehammer       | 268        | 0.366   | -7.01  |               |
| 33 Shared    | Objects   | 4      | 9     | 2       | 17        | 0      | Crime   | 9.0.Crime   | Crowbar            | 283        | 0.576   | 3.18   |               |
| 33 Shared    | Objects   | 4      | 9     | 3       | 18        | 0      | Control | 9.2.Control | Door Ram           | 298        | 0.000   | 0.12   |               |
| 33 Shared    | Objects   | 4      | 9     | 4       | 19        | 0      | Control | 9.1.Control | Lock Drill         | 313        | 0.011   | 3.73   |               |
| 33 Shared    | Objects   | 4      | 9     | 5       | 20        | 0      | Control | 9.4.Control | Hydraulic Ram      | 328        | 0.000   | -3.22  |               |
| 33 Shared    | Face      | 5      | 6     | 1       | 21        | 1      | Control | 6.1.Control | Steve              | 356        | 0.343   | -1.82  |               |
| 33 Shared    | Face      | 5      | 6     | 2       | 22        | 0      | Crime   | 6.0.Crime   | Mike               | 371        | 0.000   | 6.03   |               |
| 33 Shared    | Face      | 5      | 6     | 3       | 23        | 0      | Control | 6.4.Control | Chris              | 386        | 0.432   | -3.49  |               |
| 33 Shared    | Face      | 5      | 6     | 4       | 24        | 0      | Control | 6.3.Control | James              | 401        | 0.026   | 12.63  |               |
| 33 Shared    | Face      | 5      | 6     | 5       | 25        | 0      | Control | 6.2.Control | Tom                | 416        | 2.984   | -13.90 |               |
| 33 Suspect A | Objects   | 6      | 1     | 1       | 26        | 1      | Control | 1.3.Control | Cloth              | 444        | 0.663   | 2.14   |               |
| 33 Suspect A | Objects   | 6      | 1     | 2       | 27        | 0      | Control | 1.2.Control | Duct Tape          | 459        | 0.000   | 2.53   |               |
| 33 Suspect A | Objects   | 6      | 1     | 3       | 28        | 0      | Control | 1.1.Control | Spray Paint        | 474        | 0.000   | -0.17  |               |
| 33 Suspect A | Objects   | 6      | 1     | 4       | 29        | 0      | Control | 1.4.Control | Blu Tack           | 489        | 0.000   | 3.85   |               |
| 33 Suspect A | Objects   | 6      | 1     | 5       | 30        | 0      | Crime   | 1.0.Crime   | Shaving Foam       | 504        | 0.276   | 10.31  | Head Movement |
| 33 Suspect A | Objects   | 7      | 3     | 1       | 31        | 1      | Control | 3.3.Control | Lock Picks         | 532        | 0.541   | -9.40  |               |
| 33 Suspect A | Objects   | 7      | 3     | 2       | 32        | 0      | Control | 3.2.Control | Wire Cutters       | 547        | 0.000   | -0.94  |               |
| 33 Suspect A | Objects   | 7      | 3     | 3       | 33        | 0      | Crime   | 3.0.Crime   | Bolt Cutters       | 562        | 1.005   | -5.51  |               |
| 33 Suspect A | Objects   | 7      | 3     | 4       | 34        | 0      | Control | 3.1.Control | Metal Snips        | 577        | 0.978   | 7.94   |               |
| 33 Suspect A | Objects   | 7      | 3     | 5       | 35        | 0      | Control | 3.4.Control | Hack Saw           | 592        | 1.049   | 1.39   |               |
| 33 Shared    | Scene     | 8      | 2     | 1       | 36        | 1      | Control | 2.3.Control | Lab C              | 620        | 0.000   | -0.93  |               |
| 33 Shared    | Scene     | 8      | 2     | 2       | 37        | 0      | Control | 2.1.Control | Lab A              | 635        | 0.000   | -11.18 |               |
| 33 Shared    | Scene     | 8      | 2     | 3       | 38        | 0      | Crime   | 2.0.Crime   | Lab E              | 650        | 0.080   | -0.11  |               |
| 33 Shared    | Scene     | 8      | 2     | 4       | 39        | 0      | Control | 2.4.Control | Lac D              | 665        | 0.000   | 9.00   |               |
| 33 Shared    | Scene     | 8      | 2     | 5       | 40        | 0      | Control | 2.2.Control | Lab B              | 680        | 0.000   | 8.85   |               |
| 33 Suspect B | Scene     | 9      | 8     | 1       | 41        | 1      | Control | 8.2.Control | Office B           | 708        | 0.000   | 6.56   |               |
| 33 Suspect B | Scene     | 9      | 8     | 2       | 42        | 0      | Crime   | 8.0.Crime   | Office C           | 723        | 0.686   | 9.33   |               |
| 33 Suspect B | Scene     | 9      | 8     | 3       | 43        | 0      | Control | 8.1.Control | Office A           | 738        | 0.224   | -16.74 |               |
| 33 Suspect B | Scene     | 9      | 8     | 4       | 44        | 0      | Control | 8.4.Control | Office E           | 754        | 0.000   | -11.34 |               |
| 33 Suspect B | Scene     | 9      | 8     | 5       | 45        | 0      | Control | 8.3.Control | Office D           | 769        | 0.000   | -9.84  |               |

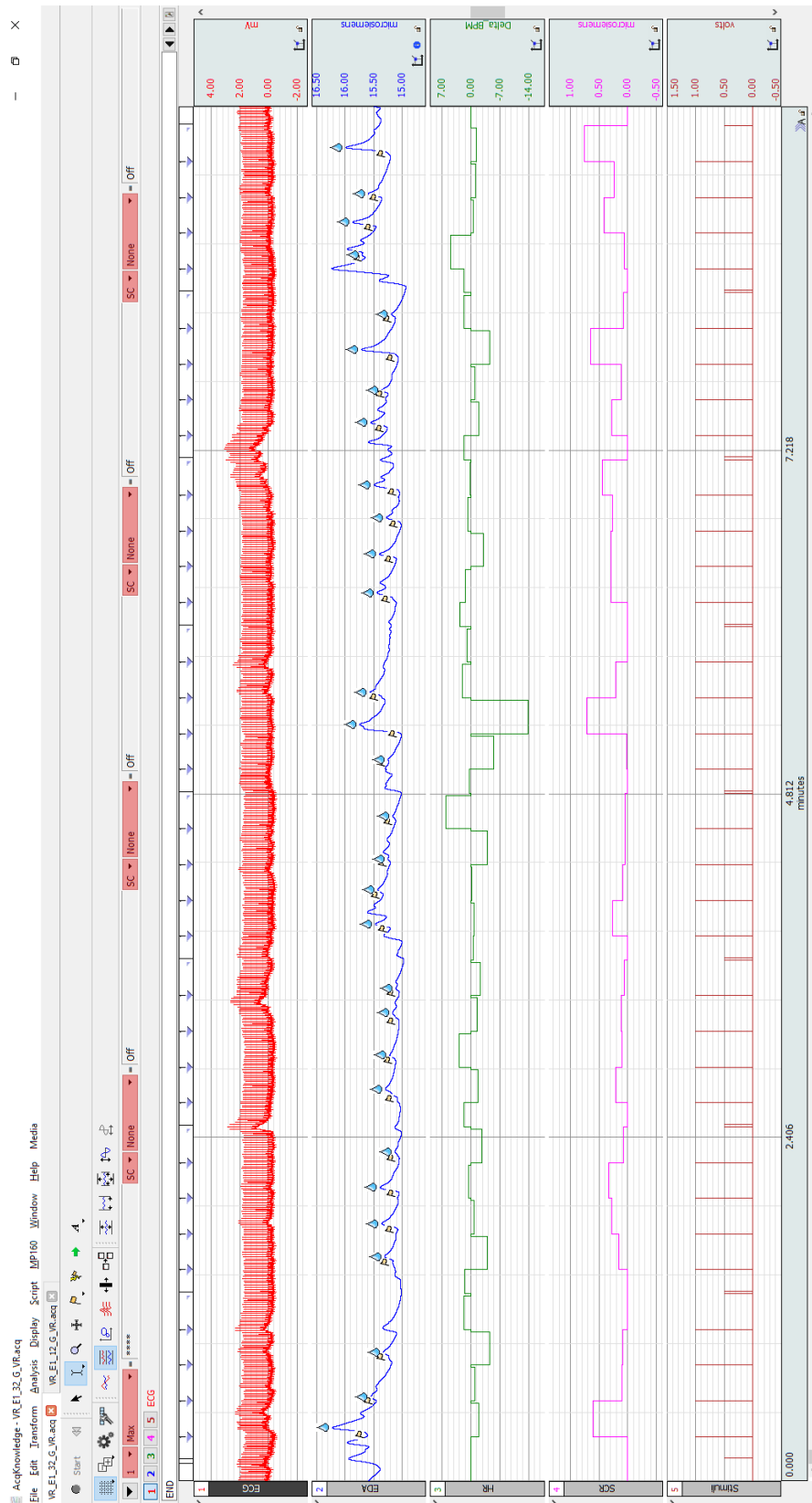


Figure A.168. Acqknowledge Data (from Caught Virtually Lying, Guilty)



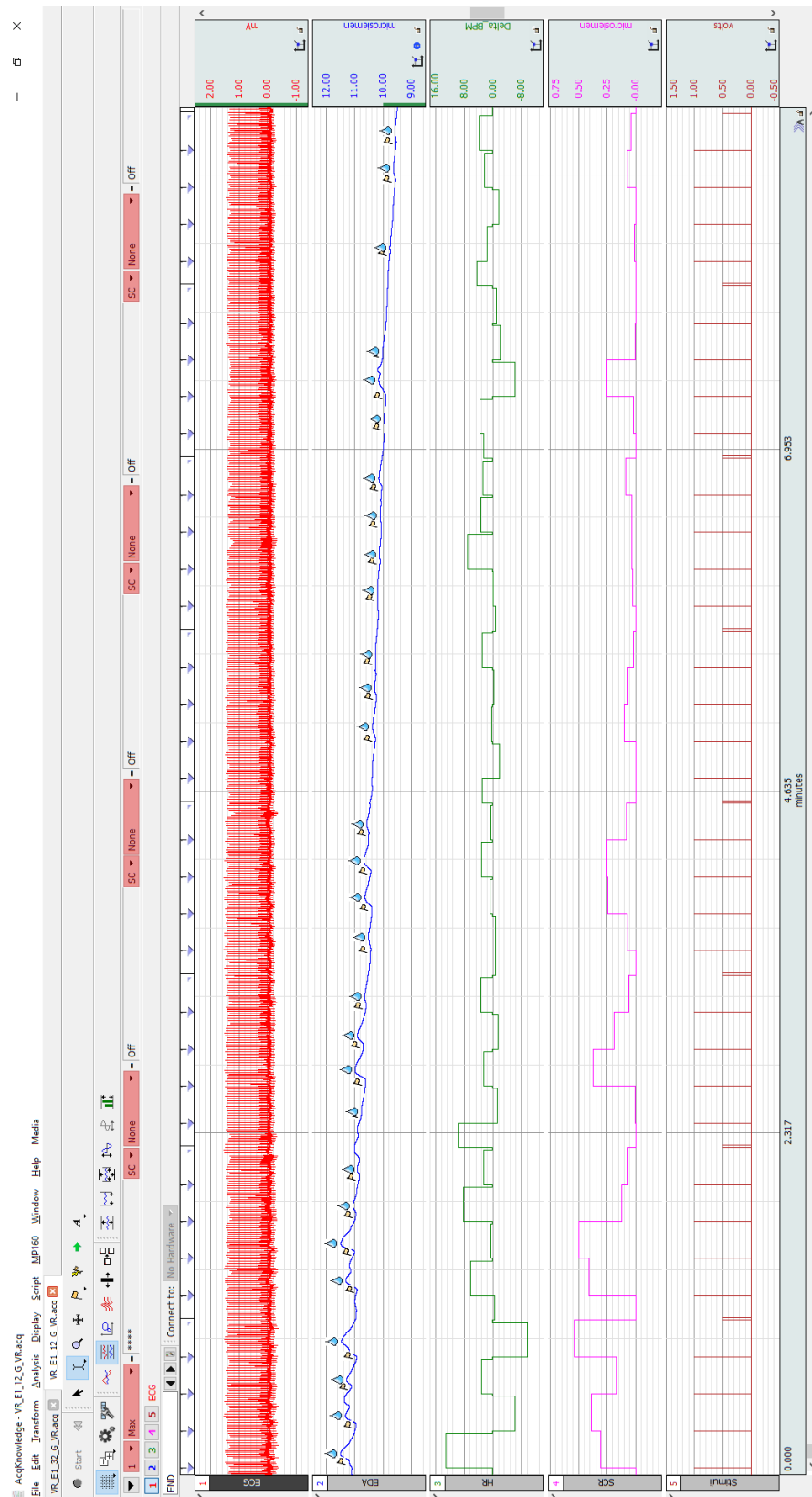


Figure A.169. Acqknowledge Data (from Caught Virtually Lying, Innocent)

## **APPENDIX 4**

### **TIMELINE AND UNFINISHED STUDY**

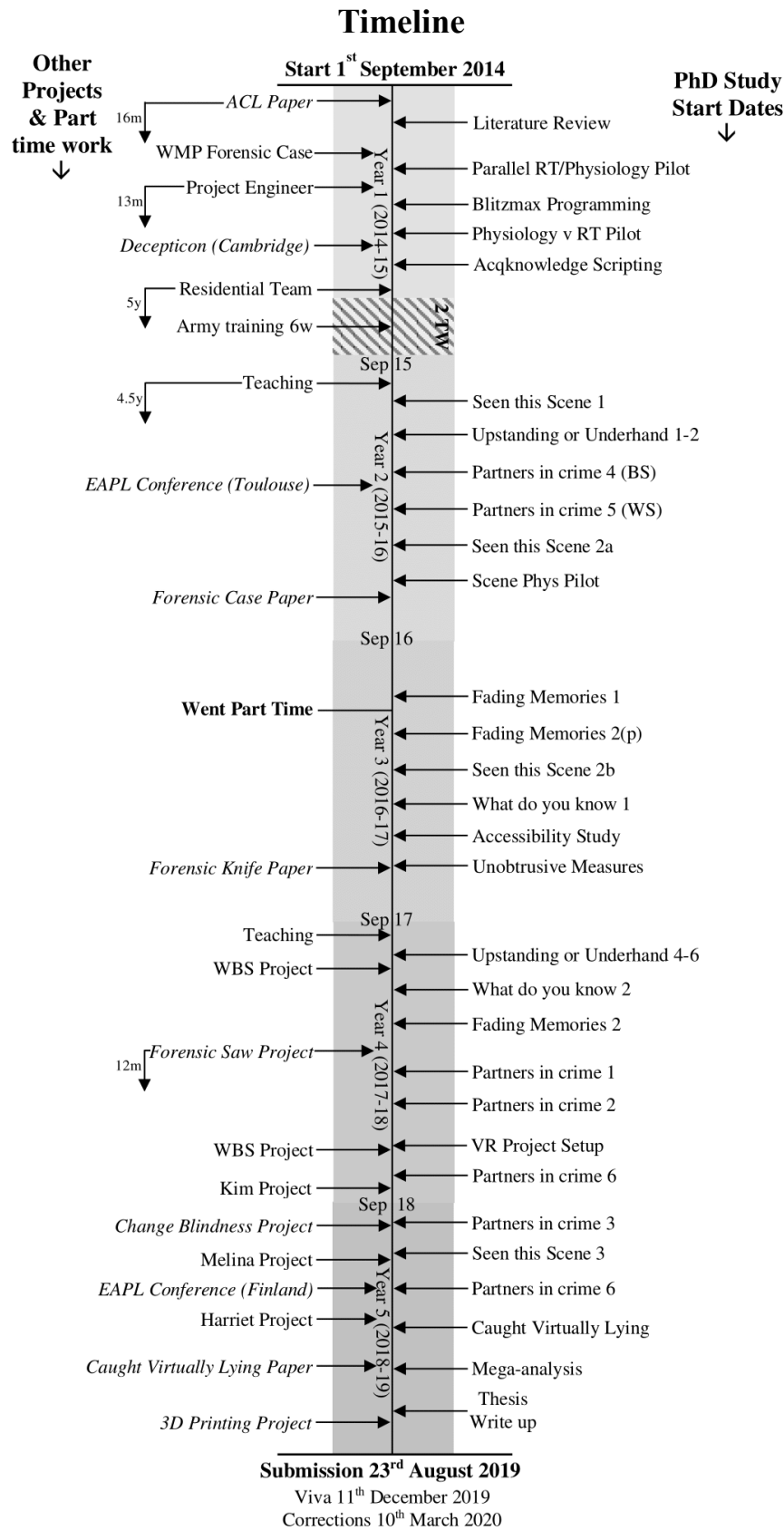


Figure A.170. Experiments, publications (*italics*) and part time work during PhD

**Unfinished Study**

## **From Lab to Law Enforcement: Potential use of the Concealed Information Test in UK Homicide Cases**

**Introduction.** In a forensic context, the CIT requires some initial conditions that need to be fulfilled for validity. Firstly the critical information used to construct the Crime items must not be known to any suspects before testing (i.e. they could be innocent suspects). Secondly there must be information available from a crime that is salient, significant to the case and unique. These requirements are significant limitations to CIT applicability and indeed a review of old cases by the FBI indicated that the CIT could only be used in 15% of cases. However, Japanese CIT examiners suggest that they can typically find more appropriate items from a crime scene than can be found in post hoc records and a plan to keep information secret is put in place. This study aims to, review previous homicide police cases in the UK, using the West Midlands Police's Homicide database, to determine the frequency of cases where a CIT could have been correctly administered.

**Method.** The thorough and meticulous nature of police investigations often results in the documentation of a vast amount of information including but not limited to witness statements, police officer statements, interview statements, forensic and digital evidence. In complex investigations such as those concerning homicide, production of hundreds of separate documents by numerous officers is typical. Towards the end of their investigation the police will summarise

supporting evidence into a case report which is then passed onto the prosecution team. Based on the examination of a selection of these reports, along with consultation with the West Midlands Police (UK), the authors established that they contained sufficient detail needed for the present study. Other relevant material that is not used in the case is revealed to the prosecutor via disclosure schedules, in particular highlighting material that undermines the prosecution case or supports the defence case. These case reports were sourced from the West Midlands Police Homicide Database, HOLMES by a specialist Force CID Officer. The HOLMES database pools all information collected by the West Midlands Police for each homicide investigation and the samples examined cover the period from 2013 to 2016 and they includes the final case report summarising the details and information from the investigation. All possible case reports between 2013 and 2016 were passed onto the authors with some exceptions. Investigations that were still ongoing at the time of the collection were excluded and 3 cases of a particularly sensitive nature were withheld. Finally, cases where the final case report had been passed onto the prosecution team via hardcopy only were no longer accessible and therefore not included. With these selection criteria, 41 homicide case reports were sourced from the West Midlands Police and used for analysis in this study.

**Analysis.** To be conducted

**APPENDIX 5**

MINOR CORRECTIONS

### Minor Corrections

**Examiners:** [A] – Adrian von Mühlenen (Internal); [B] – Bruno Verschuere (External)

#### Chapter 1

1. p6: *Figure 2.1 should be Figure 1.4. [A]*

Corrected

2. *Refrain from overselling the CIT, providing a more accurate accuracy estimate for the RT-CIT (it currently reads as if the CIT would be 95-98% accurate, see p.20 and p265, but that accuracy was only achieved in a particular study by Allen et al 1992 and does not reflect the average accuracy across studies) [B]*

Updated using a recent meta-analysis study

#### Chapter 2

3. *Figure 2.6: Symbol for "objects" line should match symbol in Figure 2.5 [A]*

Corrected

4. *Reconsider the reporting of errors and use of combined RT-error measures. [A]*

Considering this in the mega-analysis (using all RT data) we find no difference between the standard RT CIT effect and the RTCIT

Effect/Error Diff,  $p = .938$ .

5. *page 43, "This is despite of error rates being similar in both Experiments 1 and 2": Although error numbers were small, they were almost double in Experiment 2 compared to Experiment 1 (I guess this difference would be significant). Please reword to reflect this increase in errors. [A]*

Corrected. T-test revealed that errors were in fact higher in Exp 2 and this was noted in the discussion

6. *P47, error analysis: There are two errors in this paragraph ("marginal", twice)*  
[A]

Corrected

7. *page 54, Figure 2.12: Twice the same graph.* [A]

Corrected with correct graphs

8. *Check statistics, e.g.,  $d=1.4$  or  $d=1.93$  (p29 vs p31),* [B]

These were checked and are correct

9. *Kleinburg should be Kleinberg (p52); Klein Selle should be with a small k, so klein Selle (e.g., p 144)* [B]

Corrected throughout

### Chapter 3

10. *Check statistics,  $p=.04$  'not significantly different' (p121)?* [B]

Corrected and recognized in discussion

11. *Make sure risks of the newly proposed procedures (shared testing in Chapter3; testing by investigator rather than a computer in Chapter4) are sufficiently recognized in the Discussion* [B]

Recognized risks at the end of the general discussion

12. *Kleinburg should be Kleinberg (p52); Klein Selle should be with a small k* [B]

Corrected throughout

### Chapter 4

13. *p166, "In the same say as Exp 1, Chapter 2, ...": Should say Chapter 3.* [A]

Corrected

14. *p170, "There was no significant two-way interaction between Suspect and Order,*



*F(1, 66) = 2.89, p = .094, ...": This effect is marginally significant, and given it is very prominent in Figure 4.5", I think it should be mentioned (with care ...) [A]*

Recognized in the discussion

15. *p175, Do participants using countermeasures show a smaller SCR CIT effect? I think a one-sentence answer to this question (or a footnote) would add value to your finding. Or you might want to add a reference to Chapter 8 (or in a publication a footnote referring to your thesis). [A]*

Added reference to Chapter 8

16. *p175, "the SCR CIT effect was larger when the investigator administered the CIT.": I think this interpretation is not quite right. It is more the SCR CIT effect was smaller when the computer test was administered second. The other three conditions produce all a very similar SRC CIT (look at Figure 4.3, effects 0.8-1.0). I think this different interpretation is more plausible, and you should take this up in the discussion (but also in the abstract and elsewhere). [A]*

Great point. I've recognized this in the discussion

17. *p181, " Mean self-reported motivation was analysed ...(line 8)": This should probably refer to "stress"? [A]*

Corrected

18. *Make sure risks of the newly proposed procedures (shared testing in Chapter3; testing by investigator rather than a computer in Chapter4) are sufficiently recognized in the Discussion [B]*

Recognized risks at the end of the general discussion

**Chapter 5**

19. Chpt 5, page 219: " $t(62) = 3.3$ " twice, might be a mistake. [A]

Checked

20. Chpt 5, page, 248, Figure 6.3: Wrong labels for lines? [A]

Corrected

21. P218: Clarify whether the smaller SCRs to control items may be an artefact of the standardization procedure. [B]

I've removed the item factor in the analysis and updated the discussion. I have also removed the item factor in Chapter 6.

Relatedly, I've also reran all physiology CIT analyse through with the item factor removed as recommendation from a recent reviewer for this chapter.

**Chapter 6**

22. Chpt 6, page 246, last 5 lines: Something wrong in reporting twice the "long delay condition". [A]

Corrected

23. Pg 248 – swap graph axis [A]

Corrected

**Chapter 7**

24. All RT analyses across the thesis but Chapter7 rely on raw RTs (in ms). Please present graphs in Chapter 7 also in ms so that the RT data can be more readily compared to those of the other chapters and to rule out that findings are due to the standardization procedure [B]

Reran analysis using the unstandardized RTs. No difference to the findings

## Chapter 8

25. Chpt 8, page 325, "*A mini meta-analysis*": Is the term "*mini*" really appropriate here? [B] AND Chapter8 represents a mega rather than a meta-analysis? [B]

Changed to Mega-analysis. I've also included some additional Figures in the mega-analysis chapter and corrected Pg315 Countermeasures in table should be frequency [D]

## All Chapters

26. Move summary of findings from the beginning of the Results section (see e.g., p29, p38, p46, p89, p168) to the Discussion section [B]

I often include a very brief (1-2 sentence) summary of the results at the start to flag up the main findings to support the readers understanding of the preceding statistics. Others have commented on the usefulness of this style and therefore I will be keeping this in the thesis.

27. For studies where no a priori power calculation was performed, please provide justification of sample size and page 46, here and elsewhere in the thesis [B] AND You should justify when the number of participants is different from previous experiments. [A]

Updated throughout thesis

28. Please clarify whether participants were randomly allocated to conditions [B]

Updated throughout thesis

